CAADRIA 2002

Proceedings of the 7th International Conference on Computer Aided Architectural Design Research in Asia

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PRELUDE

EVOLUTION of trends in the realm of computer aided architectural design (CAAD) has seen the convergence of technologies – complementing traditional tools with emerging sciences like Information Technology (IT) and multimedia applications.

This appliqué of technologies has not just expanded the scope and enhanced the realm of CAAD research and practice, but is also breaking new frontiers. This creative nexus will be realised at the 7th International Conference on Computer Aided Architectural Design Research In Asia (CAADRIA 2002) to be held at the Faculty of Creative Multimedia, Multimedia University, Malaysia, between 18th-20th April, 2002. CAADRIA 2002's theme, "Redefining Content", seeks to recognise and infuse these emerging components in the field of architecture and design with a holistic approach towards online, digital and interactive systems.

The 41 papers compiled were selected through a blind review process conducted by an international review panel. To reflect the multi-disciplinary nature of this year's conference, the chapters are arranged topically to facilitate the in-depth study of key components. The component sessions include:

- **Web Design, Database and Networks**
- **CAD, Modelling and Tools**
- **Collaborative Design, Creative Design and Case Reasoning**
- **Simulation and Prototyping**
- **Virtual Environment and Knowledge Management**
- **Design Education, Teaching and Learning**

We believe that this specialised approach will provide a deeper and more illuminating feel of the various components and their critical convergence in the field of architecture and design.

We wish to express our heartfelt thanks to our co-host and main sponsor, Teknion Malaysia, and to our keynote speakers, Hani Rashid, Lise Anne Couture and Peter Lawrence for their invaluable contribution and guidance. Our sincere appreciation also goes to our respected international review panel, the organising committees and everyone who has helped make this conference a success.

SELAMAT DATANG is a greeting that comes from the heart.

Ahmad Rafi Mohamed Eshaq
Chee Weng Khong
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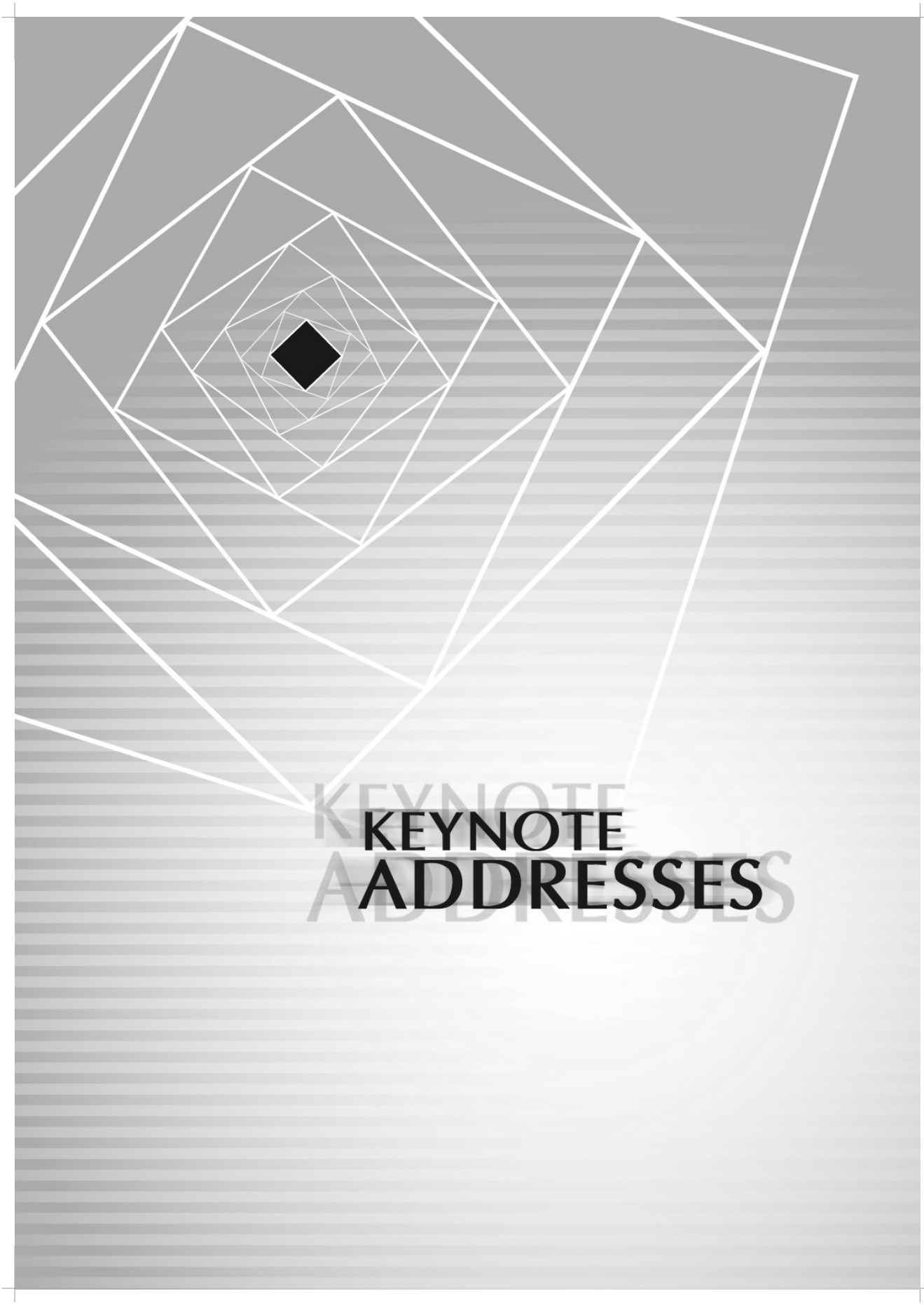
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VIRTUAL ARCHITECTURE - REAL SPACE

Keynote Speaker

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We are in the very early stages of a digital revolution whose direction we will not be certain of for sometime, much in the same way that Enlightenment-era architects, theologians, and thinkers did not quite comprehend the profound changes taking place in their own time. Today's digital technologies are having profound effects on many different aspects of our contemporary understanding from the human genome to the mapping of the cosmos. Digital manipulations that use virtual-reality technologies form a major part of this revolution. As architects we are responding in a number of ways, by conceiving of entirely new geometric principles, new methodologies, and entirely novel approaches to representation beyond perspectival geometry.

Virtual architecture is an evolving discipline that results from the convergence of data mapping and simulation, digital form making, information "architecture," and virtual reality constructs and theory. This field of research is being defined by projects and clients that differ greatly from one to another. Conventional architectures tend to be based on permanence and geometric certainty whereas virtual architecture utilises digital technologies to augment real events, time, and space. In the history of architecture, representation — whether manifest through modeling or other forms of simulation — has always been part of the architects' repertoire of conceptualising and conceiving space.

Visionaries for their time, Claude Nicholas Ledoux, Etienne-Louis Boulee, Piranesi, Bruno Taut, and El Lissitzsky are but a few examples of architects whose works can be thought of in today's context as early and important examples of virtual architecture. The Campo Marzio of Piranesi,

for example, can be reinterpreted as a data environment in which the buildings and architectures he envisioned each represent an idealised accumulation of "architectonic" information. A similar interpretation could be applied to the proto-surrealist paintings of Bosch and Grünewald. Artists and architects have always searched for the means to represent utopias, dystopias, visions, possibilities, and actualities. In many ways, virtual architecture has its deep and profound precedents in these histories of visualisation and visionary works. The computer has merely extended our ability to visualise and theorise such spatial entities.

Virtual architecture is perhaps best understood as spatiality based on the alteration of reality, on mapping flux, and on the transformable possibilities of geometry within such realms. The commission to design the Virtual New York Stock Exchange (NYSE) necessitated a proposal for a multi-dimensional interactive data environment to be used primarily as a monitoring tool by the NYSE operations group. This project's virtual architecture was based on a data visualisation paradigm, where vast amounts of information could be more easily managed through a three-dimensional, manipulable digital interface. It is important to draw a distinction here between virtual architecture and virtual buildings, just as one draws a distinction between architecture and buildings. In virtual architecture the assumption is that spatial, informational, and temporal circumstances provoke experiences and create assemblies that are tangible and plastic.

Virtual buildings, on the other hand, tend to be representations of buildings and built space as we already know them to be: for example, a virtual rendition of Le Corbusier's unbuilt Palace of the Soviets complex. This is actually virtual representation, which we tend to call virtual buildings, especially if we can inhabit them in three-dimensional representations. Virtual architecture does not represent or attempt to mimic any aspect of "real" building; rather, it is architecturally significant for entirely different reasons. The Virtual NYSE is not a rendition or re-presentation of the existing facilities: Such a version would have entailed a model with marbled textures on the walls and perhaps even avatars strolling about the floor. That kind of representation ultimately is of little value in a data-driven information environment. The three-dimensional trading floor (3DTF) supplements the main trading floor, allowing users to enter a parallel "reality" and exist in an entirely different place.

The Guggenheim Virtual Museum (GVM) was another commission that had a very unique mandate and purpose. The Solomon R. Guggenheim Museum commissioned the project as an Internet-based museum for the display and deployment of digital art and Internet-produced art, anticipating a future where new forms of expression will inevitably require new and profoundly different methods of exhibition, collection, and use. This new museum on the Web is not restrained by gravity, traditional notions of

movement and viewing, inflexible formal strategies, or the physical limits of real space. The GVM celebrates new possibilities for architecture and experience, such as fluidity, immersion, and replay. For the moment, these criteria and concepts are only possible in cyberspace and through virtual reality; however, the inevitable challenge for architecture is to bring some of these discoveries into "first reality," making them an implicit part of our new built environments in the future.

Whereas the GVM is a multi-dimensional digital interface containing "visual" clusters in the form of artist commissioned works, it also posits a situation in which virtual architecture sits alongside the experience of actual architecture. In order to explore this possibility further in the built environment, Asymptote executed various projects at the 2000 Venice Biennale, including the construction of a large scale installation situated in the Biennale gardens on the historic exhibition grounds. This physical space contained computers and Web cameras that mapped the movement of people and the architecture itself over time. This data was broadcast at a 30-second refresh cycle on the Internet. The resulting physical changes to the actual architecture enacted by Biennale visitors were recorded and viewed throughout the world in real time, which allowed distant visitors to experience architecture in this "virtualised" and mediated condition.

The Venice experiments, and others constructed in various venues, explore the notion of the real in architecture as a blurred condition: that architecture today might be comprehended as a territory located between the real and the virtual. It is important to note that although the majority of attributes we associate with virtual architecture seem to exist far from the world of constructing and building architecture as we know it, the trajectory for the future is one of inevitable convergence of these distinctions. In the future, common architecture will probably merge with what is now developing only as virtual architecture, and it will be one of the next radical breakthrough in architectural design and discourse.

At Asymptote the computer increasingly plays a vital role in all phases of the design, from sketch to engineering and through to implementation. In this way, our work is influenced by digital tools and the new theories emerging today because of them. Virtual architecture, understood here as spatial realms predicated on data and information, undoubtedly influences the ways we now understand space, form, movement, and geometry. Virtual architecture is for the moment manifest mostly within virtual space, and the Internet is a prime protagonist in creating entirely new forms of "dwelling" but virtual architecture might very well constitute the pioneer effort in forging new forms of real habitation. In other words, the territory in which virtual architecture operates and thrives is a terrific test arena for inevitable futures, and in such an arena we stand to learn a lot about the future of architecture.

Our cities are already under the influence of virtualisation, as seen in experiments such as the UCLA Computer Visualisation Lab's Virtual LA project (1998). This project set out to digitise the entire city of Los Angeles in such a way that it allowed people to inhabit a proxy-reality. People were able to view traffic flows, public-transit movement, new building development, and the status of the city's infrastructure. The proposal allowed the citizens of Los Angeles to inhabit both a virtual and a real city simultaneously. For the moment this kind of virtual-reality environment, which other cities like Singapore, Toronto, and Kuala Lumpur, are constructing, is based primarily on the existing artifact, which is extrapolated into datascapes for virtual habitation. One can imagine new models and scenarios in which urban plans and strategies begin to incorporate virtual-reality technologies and infuse buildings and infrastructure with digital capabilities that mesh the parallel realities in the future.

Eventually, our need to comprehend and explore cyberspace and virtual reality will prompt us to incorporate these and other tools within architecture, and they will become increasingly compelling. As human beings we are drawn to explore and comprehend the unknown using every capability available to us. Virtual reality holds immense curiosity for us, just as the oceans and the infinite expanse of the universe do.

DESIGNING BUSINESS

Keynote Speaker

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On a number of occasions after telling people about Corporate Design Foundation and what we do, their reaction is "well, business now understands the importance of design, right?" The answer is yes and no. There is, as they say, good news and bad news.

A growing number of senior business executives do understand the possibilities of design. But many still do not. Unfortunately, the majority of mid-level managers do not. While there has been an increasing amount written about design in the business press, there has also been an equal amount in the general press which is misleading or just wrong. There is a great deal more to do.

We should probably begin with a definition. Design is a process that produces all of the things around us. If it did not grow or was not here already, somebody designed it, very often badly. It is a process that produces all the physical manifestations of organizations. In summary, the results are all forms of communications, products, and buildings. Design is about both appearance and performance. It is both form and function. Whether the design is a piece of printed material, a product, or a building, the end result must be easy to understand and use, as well as attractive.

You may have a great looking building, but as Donald Norman has aptly pointed out so often, most recently in *The New York Time*s, if you can not easily locate the entrance of a building and quickly figure out how to open the door—the designer or architect has failed.[1] The PalmV is a phenomenal success because it is both elegant and simple. It is easy to understand, easy to use, and does not try to be everything to everyone. People rave about the design of our magazine *@issue:,* done by Kit Hinrichs and others at Pentagram. But it is more

than elegant, it's easy to read. Our illustrations and captions make things easy to understand. One of the stories we've reported in *@issue:* is Tupperware.[2] Tupperware was reinvented under the design leadership of Morrison Cousins who for ten years provided exceptional examples of great performance and appearance in Tupperware products. We have unfortunately lost this design leader, Morison Cousins passed away last year.

While working on this article, I called RitaSue Siegel, thinking if anyone should know if things are changing, she should. Her company, RitaSue Siegel Resources, a search consultancy for senior creative and design management, is now part of Aquent. RitaSue feels that today many more business people know that they need design than did three years ago. A lot has changed in the past three years, senior executives in marketing, product development, and engineering understand design or they would not have gotten where they are. Now, you could say that this is a self-fulfilling prophecy. The people who get it go to RitaSue because they need design talent. The ones we need to work with are the people who do not call her. So, there is still work to be done, but let us look at what has changed. But it was particularly encouraging when I spoke to RitaSue in February, she said that activity in Product Design and Development was 'surprisingly good'.

There are a growing number of business success stories that we continue to write about in *@issue:*. The PalmV, designed by IDEO.[3] IBM's long term commitment to design which has been re-energized under Lou Gerstner's leadership and commitment to all aspects of design – their products, their communications, and their buildings.[4] Sam Farber founded OXO Good Grips on the principles of universal design and the company grew 50% per year for the first six years of its existence.[5]

There are others we haven't heard about. RitaSue told me about some of the companies that are constantly calling her – the unknown design stories. She told me about a call she got from a company that manufactures windows and doors. The caller said to her, and I paraphrase:

> I'm a VP of marketing and product development. I just came to this company and I found that we have two engineers in product [development]. I know they need an industrial designer – how could they possibly think that they are going to come up with products that people are going to like without an industrial designer? There's a young guy here who really seems to get it, an engineer. The older guy doesn't know what the hell we are talking about so I am going to replace him with an industrial designer.

Or, there is a copy writer/creative director at Blue Cross of New York:

> Whoever my predecessor was just giving this stuff out to every Tom, Dick, and Harry—whoever would do it cheaper. I think that we should have a look about our company. When we send something to our agents they should know that it comes from us. This is Empire Blue Cross of New York. We should have literature about us for our own employees that they should be proud of

and should be easy for them to read what their benefits are.

And there are many more of these stories. So it is changing, more managers understand design. They are not just hiring people because they were told to do so, but they understand why they need design expertise.

What has caused this? What else has changed to enable this to happen? Four things have been going on for some time that have influenced business understanding of design. The first is articles in the business press. There are more stories in the business press about design. We are particularly indebted to Bruce Nussbaum of *BusinessWeek* for his pioneering design coverage many years ago; his collaboration with IDSA on the IDEA awards; and working with AIA and McGraw-Hill on architecture awards. *Fast Company* has covered design since it began. Articles about design appear in the general press: in *The New York Times*; a recent cover story in *Wired*; a front page article in *The Boston Globe* about the Aeron Chair, and so on.[6]

The second is design evolution in retail. It began with specialty catalog companies concentrated in the San Francisco Bay area: Smith & Hawkin, Williams-Sonoma, Patagonia – high quality products presented in exceptionally high quality catalogs and later in the retail environment. On a larger scale, there is Crate & Barrel's complete attention to design, including temporary employees at Christmas getting a talk about design before they started work. All these efforts have raised the design bar, but they have been in somewhat specialized markets.

A more recent example, Target has raised general design awareness to a new level. We reported on Target's exceptional example in Volume 5 of *@issue:*.[7] Target's program began with many things including an exceptional advertising campaign featuring models wearing a paper clip blouse, or a necklace made of wrenches, and of courese, their line of products designed by Michael Graves. That relationship began when Graves was working on a scaffolding design for the Washington Monument Restoration, a project heavily funded by Target. Here is a company working with an internationally known architect and designer, Michael Graves, to design the scaffolding for the restoration of the Washington Monument. The result was liked so much by the residents of Washington DC that they wanted to keep it up longer. An exceptional program in every way that's definitely pushed the envelope. So that was a digression on the second of two changes that have taken place over some time.

Third, a new generation. Both Alan Weber, one of the co-founding editors of *Fast Company*, and George Gendron, the editor of *Inc*. feel that the recent ranks of business leaders are more design conscious. This younger generation of leaders are more visually astute than their predecessors. The new leaders in the window company and in Blue Cross New York intuitively get it. The leaders we've reported on in *@issue:*, Jeff Hawkins, co-founder of Palm; Joyce LaValle, Senior Vice President of Marketing, Interface; Kenny Kahn, Vice

President of Marketing, Muzak, all get it.

The final change that I think has influenced this increasing understanding of design is brand awareness. It's almost being talked about too much. Bernd Schmitt, Professor at Columbia's Business School, co-author of the book *Marketing Aesthetics*, and more recently *Experiential Marketing* covers this awareness of the importance of brand.[8] As this brand awareness goes up, there is usually, not always, a parallel understanding of the power of design to represent the brand promise. Alan Weber, in his interview in *@issue:,* talks about brand as "promise to the customer" –something that is more important that ever on the web, which, "is so overloaded with clutter and information, that brand becomes an important differentiator."

One of the most important events in the discussion of brand is the publication of Joe Pine and Jim Gilmore's book, *The Experience Economy*.[9] Pine and Gilmore talk about the progression of economic value from commodities, to goods, to services, to experiences. They use many exceptional examples such as coffee: moving from the commodity of coffee beans, to goods sold by Maxwell House, to the coffee service at a diner, to the experience of getting coffee at a Starbucks. The design implications of this transition are enormous.

So things are changing, a growing number of managers understand the power of design. This has been accelerated by the business press, the retail world, a new generation of business leaders and a focus on brand.

But there are still problems, or we should say opportunities. There are still a large number of mid level managers who do not understand the resource design offers. To them, it is still an unessential add-on at the end of the process. Why is this? Given the changes that are taking place, why are there still those that do not get it. I want to touch on a few of these reasons and then what you can do about it.

Tom Peters, who also was interviewed in *@issue:* says that it is "because we [executives] are literalists. We're trained as engineers. We have MBA's. Because we believe that business is a reductionist activity rather than a holistic activity." At one point in the interview, Tom told me that one of his MBA students told him that 'MBA' should stand for Master of Business Analysis, "because we never do anything real we only talk about stuff."[10]

Another reason for design not catching on with business is that, up until recently design has not been part of the business vocabulary, not part of business literature, nor part of business education. It has not been on their palette, it has not been on their radar screen. This is changing, but business has not changed enough. The majority of business publications do not write at all about design. The majority of business schools still do not have anything about design in the curriculum. Although at the Foundation we are definitely trying to change that.

An engineering focus is the other part of the problem, reported in a *US News & World Report* feature, "High Tech Overload."[11] As one subtitle read "gadgets

were supposed to make life simple, but some just make people crazy." Businesses run by engineers tend to be technology focused rather than people focused - the more features that you can throw at a person, the better. Yet, statistics from the Gartner Group show that most people use only about 35% of the technology that they get their hands on. This is as true of software as it is of hardware. The problem of this engineering focus is well reported in Alan Cooper's excellent book, *The Inmates are Running the Asylum.*[12]

The press is the final part of the problem, in particular the general press. Some articles reinforce design, but many continue to be in the Art & Leisure section, reinforcing the idea of design as style and fashion. *Time Magazine* in March of 2000 had a cover titled "The Rebirth of Design".[13] Unfortunately, the subtitle read, "Function is Out, Form is In." *Time* got it all wrong, with good design function is never out. The cover photograph of a rubber-encased radio in a bowl of water was not exactly the image to inspire business confidence. But it got worse in this cover story article. The article said that the US auto industry was finally paying attention to style, but in fact the problem the US auto industry has had was an over-attention to style. The rebirth of the American automobile industry began with the Ford Taurus and the vehicles of Chrysler, which focused on ease of use in repair as well as appearance. The designers of the Taurus got a standing ovation from a conference of service technicians because of how they made what was under the hood easy to find and identify.

So what can designers and architects do about all of this? How can you get better clients and achieve greater results whether you are a consultant or you are working in-house? And if you are a client, what can you do to advance the understanding of design? Here are seven ways you can start:

1.) ***Understand the client*** – know the client company, the industry, and the potential customers before the first meeting. Clients must be willing to commit the time to provide this information.

2.) ***Be a partner, not a consultant*** – Rich Silverstein of Goodby, Silverstein and Partners, almost yelled at me in an interview when I referred to designers as 'consultants.' Consultant, to him, is a dirty word because they are "here today and gone tomorrow".[14] Rich described Goodby, Silverstein as "partners, in it for the long haul." This is as true for in-house designers as it is for consultants. This is how designers must think of themselves - as partners.

   The way to do this is to collaborate with the other stakeholders. Collaboration is about bringing together a wide range of ideas. Designers are exceptional integrators, but it is also about achieving buy-in. If the client's product and marketing people are part of the process then the preferred solution is much more likely to actually happen.

3.) ***Be strategic in your thinking, not tactical*** – The designer may have been asked for a tactical solution and should respond to this. But also, using knowledge of

potential customers, the industry, and the company, the designer should present more long term strategic options. This must be done in the language of business, addressing how business goals will be reached.

4.) ***Read the business press***—*BusinessWeek, Fast Company, The Wall Street Journal, Harvard Business Review*. Designers and clients must do this to understand what's going on in business, but also to be aware of the design success stories in *BusinessWeek* and *Fast Company* (and occasionally others). For example, a recent issue of the *Harvard Business Review* had an article entitled "Enlightened Experimentation: The new imperative for innovation," by Stefan Thomke.[15] This article talks about the importance of experimentation. Thomke says "experimentation lies at the heart of every company's ability to innovate." He goes on to talk about the importance of "failing early and often but avoiding mistakes", and the role of designers in creating prototypes enable this to happen.

5.) ***Public Relations*** – As the publishers of *@issue:*, we get a lot of press releases from design firms. I can not overestimate how bad they are. They are irrelevant and useless. Almost all of them end up in the trash. Who cares that so-and-so was promoted to chief designer or partner? Designers must rethink the PR process and get out success stories in the language of business. How is design part of a business success story? In *Wired Magazine's* January 2001 issue devoted to design, the story "flash forward" about Polaroid's five year design plan happened because of the efforts of Dave Latori, Polaroid's director of industrial design.[16]

6.) ***Stretch*** – Designers should not hold back a wild idea that you think the client will never go for. I hear stories from design firms that the solution chosen by the client was the one that they thought they would never accept. Given the increasing awareness of design, companies are going to designers for innovation – give it to them. Many companies should try this more often. Successful stretching requires two sides: the designer and the client.

7.) ***Education*** – Encourage interdisciplinary university courses that bring together students and faculty from business, design and at least one other discipline. If successful design is a collaborative process, then it would be a good idea to start doing this as soon as possible. Corporate Design Foundation has had a great deal of success in encouraging and facilitating interdisciplinary product development courses that bring students and faculty from business, engineering and industrial design together in courses. We are now using these successful courses as examples to establish other kinds of interdisciplinary courses about communication and the design of the workplace.

To help you achieve these goals I offer Corporate Design Foundation as a partner. I was asked to tell you a little bit about the Foundation, so let me do it here. Corporate Design Foundation was established to promote an

understanding of design by working with business schools to have design become a part of the business school curriculum. The mission of the Foundation is to improve the quality of life and effectiveness of organizations through design. We work to establish interdisciplinary courses that bring students and faculty from design, business, and other disciplines together in interdisciplinary courses about product development, design of the workplace, or communication. What is most convincing to executives and business school students are success stories, examples where the understanding of design has made a real difference to business success. So in closing, I will return to a few examples from *@issue:*

Muzak

When you say Muzak to almost anyone, you get an immediate but negative reaction: "elevators" or "elevator music."[17] In 1997 this well known company was in trouble. According to Kenny Kahn, who had recently become Vice-President of Marketing, the company had "insufficient cash flow, increased debt, negative growth, and an horrible corporate culture." New senior management had given Kahn the mandate to revitalize the band. Muzak worked with designers at Pentagram to first analyze what the situation was. Negative perception based on an old idea of the company was holding the company down. The company's visual identity was so fragmented that it looked different in every city and region.

The opportunity was to communicate how Muzak's audio architecture can capture and project a brand, whether in a restaurant, a store or a company. The design objective became to shift from communicating about the science of background music, to the "art" of what Muzak could do for a company. To communicate that Muzak was about emotion and what they could do for a company, Pentagram developed a complete identity including a logo, visual vocabulary, a wide range of products, and a variety of media – from stationary to signage – and promotional brochures to vehicles. With the Seattle software company, Saltmine, Pentagram developed a multimedia sales presentation for a laptop computer entitled "In Motion." They did not just present what Muzak did, but engaged individuals in exploring the essence of what music can do for a company.

The final phase for the transformation of Muzak was a new corporate headquarters, designed by Pentagram partner Jim Biber. As part of the transformation of the company they moved, from Seattle to Fort Mill, South Carolina, into a new headquarters building that expressed the company Muzak had become. Kenny Kahn describes working with the architect, "Jim helped us figure out what sort of culture we wanted to create and was able to bring concepts from around the world into the design." The headquarters is now a destination for clients. Its open, exciting environment gives clients confidence

to trust their audio identity to Muzak. In talking about the design and work done with Pentagram, Kahn commented: "Pentagram gave us a visual foundation that let us actively and creatively show people what music can do for them. Design has not only been great for Muzak's business; design has given Muzak its soul."

Fast Company

In an interview with Alan Webber, one of the co-founding editors of *Fast Company*, he said the following: "Design was a key element from the start. We felt the magazine had to be as much a personal tool as a laptop, cell phone, or pager."[18] Here is somebody who really understands that design is about both form and function. Before there was a magazine when it was just an idea, Alan spoke about "prototyping the company" by working with Roger Black, an exceptional magazine designer. He spoke about having a very handsome prototype of the magazine done by Black and the fact that "his credibility aided our credibility." Webber felt having this prototype was an important factor in Mort Zuckerman providing funding to launch Fast Company. One of the things I stress when talking to corporate executives or business school students, I ask them to think of designers as someone who speaks a language that everyone understands. They are experts of speaking the language of models – one and two-dimensional representations of some future reality. An extremely important resource, not just for the next product line or annual report, but for discussions about what the company really wants to be.

Alan said something else to me which did not make it into the final interview: "Designers have a moral responsibility to think of themselves not as people who add the frosting on to the cake – but are in the kitchen when you're discussing what goes into the cake in the first place."

I will leave you with a final thought from Steve Jobs, CEO of Apple Computers, "design is the fundamental soul of what we create."

Endnotes

[1] Kenneth Chang, "From Ballots to Cockpits, Questions of Design," *New York Times* (23 January 2001): 1, 4 (Science).

[2] Corporate Design Foundation, "Tupperware Shows its Colors," *@issue: The Journal of Business and Design,* Vol. 5, No. 1 (Spring 1999): 6-13.

[3] Corporate Design Foundation, "Beyond Techno Gadget," *@issue: The Journal of Business and Design,* Vol. 6, No. 2 (Fall 2000): 16-23.

[4] Corporate Design Foundation, "Big Blue Reinvents Itself," *@issue: The Journal of Business and Design,* Vol. 4, No. 2 (Fall 1998): 16-25.

[5] Corporate Design Foundation, "Getting a Grip on Kitchen Tools," @issue: The Journal of Business and Design, Vol. 2, No. 1 (Spring 1996): 16-24.

[6] Beth Healy, "The Seat of Power," Boston Globe (2 February 2001): A1, A14.

[7] Corporate Design Foundation, "Targeting Design," @issue: The Journal of Business and Design, Vol. 5, No. 1 (Spring 1999): 26-31.

[8] Bernd Schmitt and Alex Simonson, *Marketing Aesthetics: The Strategic Management of Brands, Identity, Image,* (New York: The Free Press, 1997); Schmitt, *Experiential Marketing*. (New York: The Free Press, 1999).

[9] Joseph B. Pine II and James H. Gilmore, *The Experienced Economy: Work is Theatre & Every Business a Stage* (Boston: Harvard Business School Press, 1999).

[10] Corporate Design Foundation, "Tom Peters on Design," *@issue: The Journal of Business and Design,* Vol. 6, No. 1 (Spring 2000): 3-5.

[11] James Lardner, David LaGesse, and Janet Rae-Dupree, "High-tech Overload," *US News and World Report* (15 January 2001): 31-36.

[12] Alan Cooper, *The Inmates are Running the Asylum: Why High-Tech Products Drive Us Crazy and How to Restore the Sanity,* (Indianapolis: Sams, 1999).

[13] Frank Gibney, Jr. and Belinda Luscombe, "The Rebirth of Design," *Time* (20 March 2000): 66-75.

[14] Rich Silverstein, *Business, Design & Communication: The Reedy Memorial Teleconference* (transpcript), (Rochester Institute of Technology, 1997).

[15] Stefan Tomke, "Enlightened Experimentation: The New Imperative for Innovation," *Harvard Business Review* (February 2001): 67-75.

[16] Jessie Scanlon, "Flash Forward: Polaroid's five-year plan," *Wired Magazine* (January 2001): 170-176.

[17] Corporate Design Foundation, "Muzak on Key," *@issue: The Journal of Business and Design,* Vol. 7, No. 1 (Spring 2001): 16-23.

[18] Corporate Design Foundation, "Alan Webber on Design," *@issue: The Journal of Business and Design,* Vol. 6, No. 2 (Fall 2000): 3-5.



1 WEB DESIGN, DATABASE & NETWORKS

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DIGITAL CAADRIA-PROCEEDINGS: RETROSPECTIVE ANALYSIS OF CONTENT

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Abstract. This contribution issues an overview of the frame conditions for the utilization of Digital CAADRIA Proceedings representing in its entirety an important asset for the CAAD-community. The process of the extended use of electronic copies of CAADRIA conference papers in pdf-format is described as well as the respective decisions taken in this context. Results of a content analysis regarding the topics of CAAD and referencing are presented.

1. Background

Annual conference activities of CAADRIA started in 1996 with an initial output of 31 full papers, published on 316 pages. Since 1997 the number of papers has steadily increased to approx. fifty at present. In the framework of these conference proceedings, all in all 285 papers were created amounting to a publication output of 2.775 pages for the period 1996-2001. CAADRIA is a lively association and the knowledge-base is expanding from year to year. Therefore, it is of interest to which extent this information has become accessible and has been analyzed as to substance matter. So far, CAADRIA has been focusing on paper-based proceedings. Generally spoken, smaller editions of such proceedings seem to be safely stored away in the studies of faculty members, but hardly become widely available to the (scientific) public. A wise decision was taken by the CAADRIA-board to reproduce previous conference proceedings in pdf-format and thus enhance the potential of wide access at low cost. Most of the material was archived in

digital format and could therefore be converted easily without the necessity of scanning paper-based materials and performing optical character recognition (ocr).

2. Concept of On-line Access: CUMINCAD

In fall 2001 all CAADRIA proceedings were reproduced in pdf-format, aiming, however, at presenting the original layout, traced back to the original proceedings. Wishing to be able to create the best-possible match of the original, the alternative i.e. html-documents was not pursued, as problems with page breaks etc. may occur. Though most of the pdf-documents were directly reproduced from the original program documents the annual volumes 1996 and 1997 had to be scanned in as digital specimens were not available.

Having made these materials available in a digital format and thus potentially enabling enhancement of accessibility, the framework for extended use has to be specified. E.g. a complete indexed file for off-line use (CD-ROM) could easily be created, but respective decisions have to be taken by the CAADRIA-board. In the framework of this paper the on-line use will be focused on, i.e. a collection of stand-alone pdf-files in connection with the CUMINCAD-database (http://itc.fgg.uni-lj.si/cumincad/). CUMINCAD, an acronym for "Cumulative Index on CAD", is a bibliographic index compiling papers related to Computer Aided Architectural Design (Martens and Turk, 1999). This work started in 1998 on a shoestring budget and helps focusing on future CAAD education and research activities. Implemented with a database, it allows searching and browsing in the ways usual on the Web. It provides a "historical evolution" to learn from previous efforts and draws attention to older original works that could have been ignored because they could not be found otherwise. CUMINCAD thus supports free of charge the search and the dissemination of CAAD-related publications. Presently, all major CAAD conference proceedings (ACADIA, CAAD futures, CAADRIA, eCAADe, SiGraDi) are recorded in CUMINCAD. If, however, a record is of interest, it might be rather difficult to retrieve the corresponding full paper and then it seems useful to retrieve the pdf-paper immediately without delay.

The result of digitization should not be treated as just another collection of papers; e.g. an overview of the knowledge-base could be created (Martens, Turk and Cerovsek, 2001). This way also the authorship can count on improvements regarding dissemination of their publications. CAADRIA, furthermore, has a relatively large number of papers from PhD-students whose access to "free electronic publications" seems to be of particular importance in terms of full papers to be retrieved at hardly any costs (Tenopir and King, 2000). Due to the current CUMINCAD-policy three

stages of availability are provided. *Anonymous access* only provides access to bibliographic data, however. E-mail address entry makes the user a "*friend*" also having access to the summaries. At present *full access* is only available to eCAADe- and CAADRIA-members and grants access to stored pdf-documents (at the time of writing approx. 800 papers). Digitization of SiGraDi proceedings has been scheduled for the first half and of ACADIA proceedings for the second half of 2002.

3. Objectives and Results Concerning Analysis of Content

Ontology of a scientific field typically includes a taxonomy that breaks up the field into several topics. The taxonomy is e.g. implicitly present in the organization of conference proceedings. In the framework of a conference paper which was focusing on the machine's perspective regarding the topics of CAAD (Turk, Cerovsek and Martens, 2001) efforts to use the machine learning and data mining techniques to automatically group papers into clusters and to create a set of keywords labeling a cluster were presented. The hypothesis was that an algorithm would create clusters of papers automatically and that the clusters would be similar to the groupings a human would have made. Several algorithms for performing such an analysis like that were investigated, but the researchers were unable to prove the original hypothesis. The main conclusion consequently stated that it requires more than objective statistical analysis of the words in abstracts to create ontology of CAAD.

For this reason "human expertise" expressed in previous *calls for papers* (so called "topics of interest") as well as the *session labels* from previous CAADRIA conferences in the period 1996-2001 were collected. The alphabetical list of topics including more than one hundred entries was compressed for reasons of better accessibility into less than a third of the original length. Similar or identical terms were thus pooled and the number of quotations was added in brackets. Subsequent conference chairs naturally will look into the papers of the previous events. Major changes are to be registered particularly concerning the first CAADRIA conference and the following conferences, a fact readily understandable considering the provisional positioning of the new conference platform in the year of the foundation 1996.

Table 1 illustrates the attempt of finding a connection between the *topics of interest* and the *session labels* appearing in the conference proceedings. Another compressing was performed to this end (original number: 50 labels). Matching labels, however, could not be spotted for 11 topics listed in the *call for papers* and furthermore, the problem of *similarity* and *closest match* turned up.

TABLE 1. Overview on the topics of CAADRIA with corresponding session labels.

Call for Papers: Topics (1996-2001)	**Sessions labels (1996-2001)**
Building System Engineering and Analysis [3]	Application and Analysis of Architecture
CAAD Teaching and Research Directions in Asia [2]	Research Directions (Data and Knowledge) / Perspectives in Teaching [3]
Case-based Reasoning [4]	
Cognitive Studies in Design [3]	Cognitive Design Methods
Computer-based Design Methodologies	
Computers & Design Pedagogy / Digital design education [2]	(Design) Education / Curricula and Teaching Applications [3]
Construction Robotics [3]	
Cooperative/Collaborative Design [4]	Cooperative/Collaborative Design [5]
Decision Support Systems [3]	
Design Creativity / Design Evaluation [5]	
Design Kinematics and Animation [3]	
Digital/Electronic Design Media [6]	Digital Media and Design Education / Design Tools [3]
Environmental Simulation [4]	Simulation [2]
Generative Systems [5]	Generative Design/Systems [2]
Geographic Information Systems [4]	Regional Information and Information Delivery System
Human Computer Interaction [5]	Human Computer Interface / Interaction and Industrial Design [2]
Information Delivery Systems for Design [3]	Information (Delivery) Systems / Modeling / Structure and Management [4]
Integrated Building Models	
Knowledge-based Design Tools - AI [3]	Knowledge Representation
Models of Design [3]	Design Modeling / Process / Concepts / Creativity [5]
Precedence and Prototypes [4]	Precedence and Prototypes [3]
Prediction and Evaluation [4]	Prediction and Evaluation [3]
Rapid Prototyping [3]	
Scene and Product Modeling [3]	
Shape Grammar - Shape Recognition and Emergence [7]	Shape Studies and Grammars resp. Generative Systems [3]
Space Planning & FM [3]	
Trends in Practice [4]	
Virtual Reality / Virtual Architecture [6]	Virtual Reality and Automation / Digital Scene / Computer Media – VE's [5]
Web-based (Collaborative) Design [2]	Teaching Tools [1]

Therefore, the findings presented below are to be regarded as an approximation. Subsequently, the 19 session labels were linked with 268 of the total of 285 papers (17 papers not assigned to any session) in order to determine frequency distribution.

TABLE 2. Ranking of session labels and corresponding CAADRIA-papers (1996-2001).

Sessions labels	**Papers**
Virtual Reality (...) / VE's	34
Cooperative/Collaborative Design	31
Shape Studies and Grammars resp. Generative Systems	30
(Design) Education / Curricula and Teaching Applications	20
Design Modeling/Process/Concepts/Creativity	20
Information (Delivery) Systems (...) and Management	19
Research Directions (...) / Perspectives in Teaching	17
Prediction and Evaluation	17
Digital Media and Design Education / Design Tools	15
Precedence and Prototypes	14
Simulation	9
Regional Information and Information Delivery System	9
Generative Design/Systems	7
Knowledge Representation	7
Human Computer Interface / Interaction and Industrial Design	6
Application and Analysis of Architecture	5
Teaching Tools	5
Cognitive Design Methods	3

As a rule conference papers contain references specifying their positioning within the particular context of topics. With a few exceptions this applied to most CAADRIA-papers and any research work to this end cover the period of 1998-2001 (1996 and 1997 are missing, because the pdf-files are just scans without ocr). Approx. 200 papers indicated a total of more than 2.000 references, which means that the average number of citations per paper is 10. These references were taken from pdf-files and broken down into four components: author(s), year, title and source. Even though this splitting up was performed by means of program routine manual re-editing was necessary as the uniform quotation manner is not available in all cases. Table 3 shows a "TOP 23", based on a minimum of 10 references (as first authors). Therefore, e.g. a publication of "Schön und Wiggins" quoted thirteen times is not listed separately, but subsumed to "Schön".

TABLE 3. Ranking of authors in CAADRIA-references (1996-2001).

Rank	Author	Number of references
1	Mitchell, William J.	43
2	Schön, Donald A.	37
3	Liu, Y.T.	36
4	Stiny, George	34
5	Gero, John S.	32
6	Chiu, Mao-Lin	27
7	Suwa, M.	27
8	Goldschmidt, G.	25
9	Akin, Ö.	24
10	Maher, Mary Lou	22
11	Koutamanis, A.	18
12	Sasada, Tsuyoshi	18
13	Woodbury, R.F.	17
14	Simon, H.A.	16
15	Cross, N.	13
16	Coyne, Richard	12
17	Kaga, A.	12
18	Kurmann, David	12
19	Morozumi, Mitsuo	11
20	Oxman, Rivka E.	11
21	Eastman, C.M.	10
22	Frazer, John	10
23	Wojtowicz, J.	10

Practically a quarter of the total number of references is included in this "TOP 23". The following table contains the most frequently quoted references and it surely comes as no surprise that all of the authors listed below also appear in Table 3.

Publications in books are not as common and the Magazine *Design Studies* ranks as the most frequently enumerated source of publication. Naturally the rankings presented in this contribution may be regarded as mere academic playfulness. Despite the fact that the field of conceivable combinations has not been fully covered an attempt is made not only to gather experience acquired resulting from conference activities in form of publications, but also to make specifications as to their substance matter and here a certain concentration on the most quoted publications can be noticed. Even though such a scope of knowledge may be particularly useful regarding newcomers, a snowball effect is to be avoided by all means.

TABLE 4. Ranking of references in CAADRIA-references (1996-2001).

Reference	
Schön, D.A. and Wiggins, G.: 1992, Kinds of Seeing and Their Functions in Designing, in *Design Studies*, 13(2), pp. 135-156.	14
Schön, Donald A.: 1983, *The Reflective Practitioner: How Professionals Think in Action*, Basic Books, New York.	13
Mitchell, William J.: 1995, City of Bits - Space, Place and Infobahn, MIT Press.	9
Suwa, M., Purcell, T. and Gero, J.S.: 1997, Macroscopic Analysis of Design Processes Based on a Scheme for Coding Designers' Cognitive Actions, in *Design Studies*, 19(4), pp. 455-483.	8
Mitchell, William J.: 1990, *The Logic of Architecture: Design, Computation and Cognition*, MIT Press, London.	8
Sasada, Tsuyoshi : 1995, Computer Graphics as a Communication Medium in the Design Process, in *The Global Design Studio* [Proceedings CAADFutures 95, Singapore], pp. 3-5.	7
Goldschmidt, G.: 1994, On Visual Design Thinking: The Vis Kids of Architecture, in *Design Studies*, 15(2), pp. 158-174.	7
Goldschmidt, G.: 1991, The Dialectics of Sketching, in *Creativity Research Journal*, 4(2), pp.123-143.	7
Stiny, G. and Mitchell, W.J. : 1978, The Palladian Grammar, in Environment and Planning B (5), pp. 5-18.	7
Liu, Y.T.: 1996, *Understanding Architecture in the Computation Era*, Hu's, Taipei.	7
Wojtowicz, J. (ed.): 1995, *Virtual Design Studio*, Hong Kong: Hong Kong Univ. Press.	7
Suwa M. and Tversky B.: 1997, What Do Architects and Students Perceive in Their Design Sketches? A Protocol Analysis, in *Design Studies* 18 (4), pp. 385-403.	7
Mitchell, William J.: 1995, *City of Bits*, MIT Press, Cambridge (MA).	7
Mitchell, W.J. and McCullough, M.: 1991, *Digital Design Media*, VNR, New York.	6
Liu, Y.T.: 1996, Restructuring shapes in Terms of Emergent Subshapes: A Computational and Cognitive Model, in *Environment and Planning B*, (23), pp. 313-328.	6
Liu, Y.T.: 1995, Some Phenomena of Seeing Shapes in Design, in Design Studies, 16(3), pp. 367-385.	6
Simon, H.A.: 1992, *The Science of the Artificial*, MIT Press, Cambridge (MA).	6
Stiny, George: 1980, Introduction to Shape and Shape Grammars, in Environment and Planning B (7), pp. 343-351.	5
Akin, Ö.: 1986, Psychology of Architectural Design, Pion, London.	5
Chiu, M.L.: 1997, Representations and Communication Channels in Collaborative Architectural Design, in *Proceedings Third International IFIP WG5.2*, pp.77-96.	5

4. Conclusion and Outlook

Within this six-year period the published number of CAADRIA papers has become too large to issue a complete overview without relying on a computer-assisted database and to be able to recall the scope of findings resulting from all and every publication in detail. After all, we are dealing with nearly 3.000 published pages continuously increasing every year by a

further 500 pages, probably not to be handled mentally and leading to a situation of literally being "overnewsed but underinformed" Therefore, assistance regarding efficient information mastering will be gaining in significance for the years ahead. This also entails the possibility of availability to be accomplished at low cost by means of electronic papers.

The references quoted in the papers also represent a relevant item in terms of statistics. The overview presented here is to be regarded as a first approximation as interlinking of references with each other as well as cross-linking with the CUMINCAD-records might lead to a novel way of consideration. Thus future interest may also be directed to the connection of the most quoted references and their correlating papers. In the end both the selections of the references as well as the sessions etc. are a result of human structuring ability and could be useful for machine learning efforts. While the information in which session a paper was presented, is not a typical bibliographical entry it could prove very valuable in our attempt to automatically classify or cluster the papers because this provides a training set for the classification algorithm. What is to be taken for granted is that similar paper will quote similar references, i.e. references are made to those publications connected with the individual topic. Thus determining supposed similarity of conference papers could also be performed by comparing the references given. A certain degree of fuzziness must be accepted as references occasionally are considered as mere decorative items.

Further research and even more so demonstration work will be required to point out all resulting benefits and to re-engineer parts of the scientific publication process by establishing a fully functioning on-line service, where scientific output would be available almost for free and where a virtual on-line community of authors and readers would meet. Among a set of technological tasks a corresponding research agenda will be handled in the framework of a research project called "SciX - Open, Self Organizing Repository for Scientific Information Exchange" which is funded by the EU [2002-2003, http://www.scix.net/].

References

Martens, B. and Turk, Z.: 1999, Working Experiences with a Cumulative Index on CAD: "CUMINCAD, in *Architectural Computing from Turing to 2000* [eCAADe Conference Proceedings], Liverpool (UK), pp. 327-333.

Tenopir, C. and King, D.: 2000, *Towards Electronic Journals: Realities For Scientists, Librarians, and Publishers*, Special Libraries Association.

Turk, Z., Cerovsek, T. and Martens, B.: 2001, The Topics of CAAD – A Machine's Perspective, in *CAAD futures 2001* [Conference Proceedings], Eindhoven, pp. 547-560.

RE-SEARCHING THE RESEARCH PROBLEMS IN CAAD

Data Mining in i-CAADRIA

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Abstract. This study attempts to develop an online CAAD research archive of conference papers, i-CAADRIA, and apply data mining techniques to find research patterns. Research papers are clustered for building semantic relationship. The system and early feedbacks are presented. This study suggests that smart web query and user interface can enhance our understanding of the research patterns.

1. CAAD Research

The research problems faced in the academic society are continuously expanding and varied. Understanding the previous research efforts is an important task in the development of computer-aided architectural design (CAAD). Our preliminary study found that researchers spend more time on formulating their research problems, and undertake the steps of reviewing literatures, constructing research methodologies, applying analytic or computational techniques, implementing prototype systems or conducting experiments, and finally concluding the research result based upon the previous findings. Research papers such as conference or journal papers serve as the foundation of research and often provide the impetus for further research. Consequently, researchers continuously re-search the same problems with various approaches or techniques.

The objective of this paper is to develop an online CAAD research archive of conference papers and examine the research patterns by novel information mining techniques, i.e., apply data mining techniques to study the current research paradigms and their relationships based on a research-oriented database of collected papers. This study serves both the methodological and technical purposes, i.e. to search the linkages within CAAD research paradigm and study the mining techniques.

2. i-CAADRIA: An Online Research Archive

2.1. DATASET AND KEY QUESTIONS

Currently, we have a collection of 283 research papers accumulated in the last six CAADRIA conferences from 1996 to 2001. These contain the efforts from various disciplines. The original dataset has only paper titles, authors, abstract, full text, and without keywords. A concise index file is maintained for organizing these files. The papers appeared in the proceedings are digitized and transferred into pdf format, and each paper is assigned with a unique id. Figure 1 demonstrates the paper contents on the right side and the research process on the left side, while both are related. From the research point of view, re-searching the research problems in CAAD help us understanding the trend of research topics, the problems and the approaches, the contributions, and the distribution of research units.

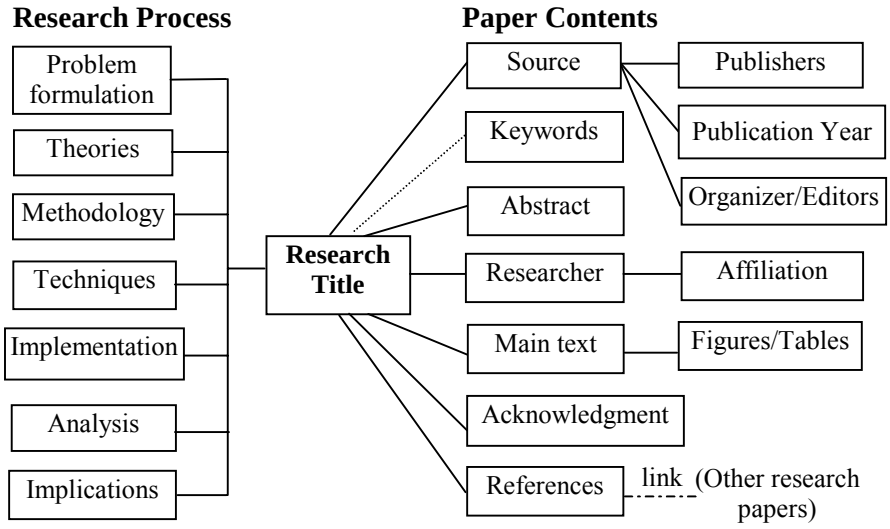


Figure 1. Research Process and Paper Contents

Furthermore, knowledge management is important in the research field for continuous development. A 6W (what, who, when, where, why, and how) approach is applied to analyze the research contents, including questions such as: What are the research problems in CAAD and who are involved in these researches? How are these problem solved? What kinds of methodologies or research paradigm are involved? What are the applications? Why are the applications important or fail? Therefore, we need an information mining mechanism to answer the above questions.

2.2. ONLINE ARCHIVE

To fulfill the research requirement, we first implement an online system, i-CAADRIA, by JAVA, ASP, and HTML to integrate with the ACCESS database. The primary function of online systems is the repository of research papers. Figure 2 demonstrates the snapshots of i-CAADRIA. CUMINCAD (CUMulative INdex on CAD) provides an example that an online database can be used as the data mining source for research [Martens and Turk, 1999]. Similarly, i-CAADRIA is an online archive on the web for sharing the resource by an accumulative process of collecting new inputs. In addition, the system is enhanced for mapping the research issues by the 6W scheme with analytic interfaces. Whether the research patterns that can be mined are represented in terms of a structure that can be examined, reasoned about, and used to inform future decisions.

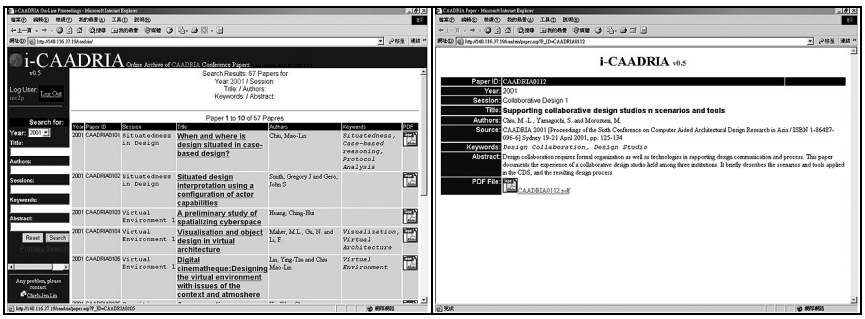


Figure 2. Snapshots of i-CAADRIA

3. Data Mining in i-CAADRIA

Data mining is defined as the process of discovering patterns in data [Witten and Frank, 2000]. In this case, the patterns are research patterns. Clustering is one of the essential methodologies in data mining to deal with a large dataset in the process of data reduction [Ciftcioglu and Durmisevic, 2001].

3.1. DATASETS

In general, related papers are classified into research domains in accordance with their relevance, Table 1. The possible correlations are among papers in terms of the research domains, techniques, or researchers. In terms of research paradigm or domains, we found that most researchers continuously contribute to the fields of collaborative design, shape semantics and knowledge representation, virtual reality and virtual environment (VE), and design education. The conference sessions are in fact the basic clusters of paper domains by organizers, while the classification is often subjective for the organizational convenience.

TABLE 1. Summary of CAADRIA Paper Research Domains from 1996 to 2001

Areas* / Year	1996	1997	1998	1999	2000	2001
Design methods and models	6	2				6
Design cognition	2	1				6
Collaborative design	3	8	5	6	4	8
Information system	1	2	7	9	8	
Digital media and human computer interaction	1	3	3	8	12	
Precedents and prototype	1	4	4	3		
Shape studies and knowledge representation	2	7	10	3	4	8
Generative systems	4	4	1	2		3
Virtual reality and VE	1	4	7	5	6	12
Simulation	1	1			6	3
Prediction and evaluation	2	7	5	4		
Regional information			3			2
Design education	8	2	3	3	8	8
Total	31	45	48	43	48	56

* Some areas are renamed and reclassified from the original sessions for comparison purposes.

3.2. CLUSTER ANALYSIS

The CAADRIA dataset is broadly divided into two categories as (1) clustering with supervised and (2) clustering with unsupervised learning. In the supervised sub-dataset, we are concerned with a collection of labeled data that come in the form of ordered pairs. This can be seen as a feature value describing the data and its class assignment. In the unsupervised sub-dataset, we start with the number of clusters assigning each pattern to a separate cluster and proceed to merge the clusters that are the closest with the distance function. Eventually, the association between the feature values and the class assignment are endeavored for determinations.

Because the research domains, analytic methods, and technologies applied are correlated with timing, the steps in data mining are undertaken as follows: (1) dividing all papers into sub-datasets in according with years, Figure 3, (2) choosing typical sample files in association with particular domains or subjects by experts, (3) scanning paper abstracts to collect keywords for building semantic relationship, (4) using the semantic relationship to analyze the entire dataset for classifying or associating relationships, and (5) evaluating and redefining the semantic relationship. For example, we start with the sample files in the field of collaborative design to study their relations in the data of year 2001, and examine the domain backward. The keywords are selected based on the frequency of occurrence in their abstracts.

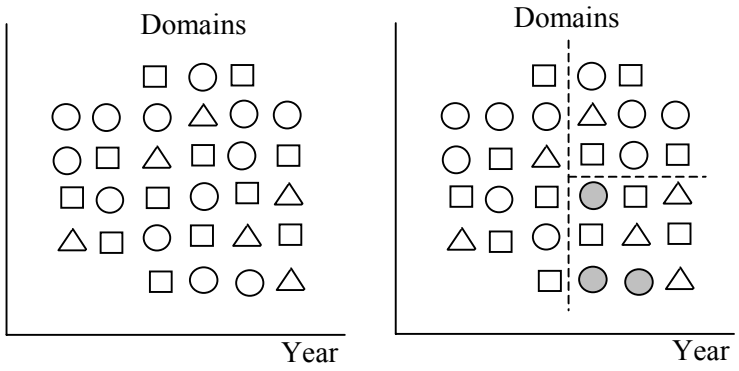


Figure 3. Subdivision of Dataset by years and domains

3.3. THE SEARCH MECHANISM

Based on literature surveys, approaches to web search include (1) syntactic search, (2) metadata search, (3) query by examples, and (4) navigational search. Currently, i-CAADRIA is implemented with three levels of search functions such as (1) general search (year, keyword), (2) detailed search (year, title, researcher, affiliation, and references), and (3) advanced search (association of features). While key information such as keywords derived from abstracts is accumulated, there are linguistics problems (such as synonymies) as well as technical problems (algorithm) in classification.

Although some attempts have been made to develop universal ontologies, context ontologies are more effective for the semantic retrieval of web data [Chiang, et al., 2001]. Therefore, we adopted the smart web query (SWQ) method proposed by Chiang, Chua and Story (2001) for exploring domain semantics (i.e., knowledge and information), and context ontologies in

selected domains are further analyzed. Figure 4 demonstrates the search engine and its components.

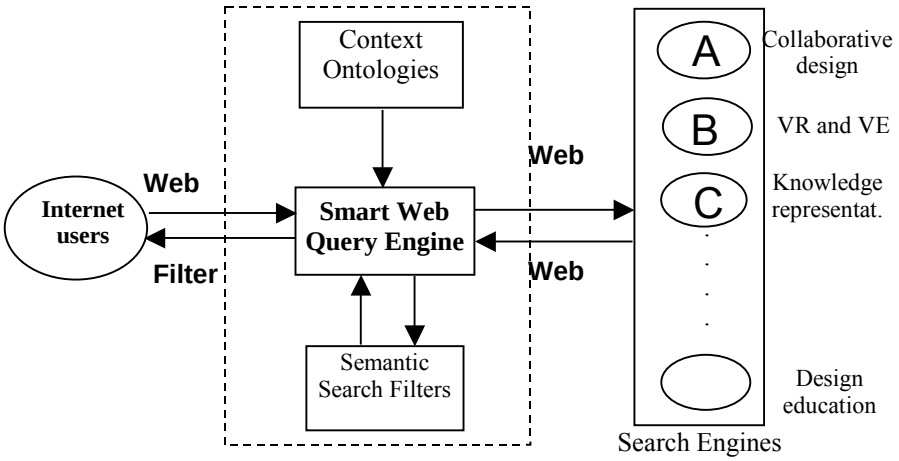


Figure 4. Search engine and its components

3.4. USER INTERFACE

Traditional information management systems use folders and focus on separating information that creates barriers between information. The result of search in dataset is often listed with detailed and separated information. On the contrary, links enable users to connect information into a network of logical association. Furthermore, visualization of association becomes more feasible and important on the web searches now [Inxight]. i-CAADRIA is implemented by the TheBrain program to visualize the associations of certain features. Figure 5 demonstrates the associations in design education (left) and collaborative design (right). Therefore, users can search or trace desired research contents through iterations of searches by selected inputs.

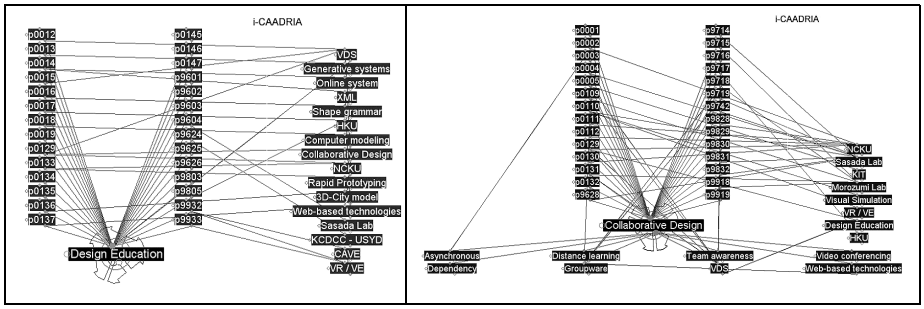


Figure 5. Association of Papers in Collaborative Design (left) and Design Education (right)

4. Discussion

4.1. MACHINE VS. HUMAN VIEWPOINT

We have compared the results of different searches. The size of information is further tested starting from 50 up to 300 papers. We found same terminologies or synonymies in the same domain. While a list of keywords is generated from the frequency of occurrences in paper abstracts, we found that there are strong and weak associations among these keywords in the dataset. Only the strong associations are useful for cluster analysis. When the number and scope of search is gradually increased, the effectiveness of association or search is improved. However, there are also limitations in data mining from the machine viewpoints [Turk and Martens, 2001]. The limitations are evident as the intelligent and learning ability. The study then attempts to enhance the search function of i-CAADRIA by a machine learning approach from both the user behaviors and research needs. On one hand, we need experts in each domain to identify the key papers for information mining. On the other hand, we need to record the user behaviors on the log files to understand their interests. Further analysis is undertaken to classify the search patterns by frequencies and association.

4.2. KNOWLEDGE DISCOVERY

We also discovered certain knowledge from the research domain and researchers about the CAAD applications. For instances, many researches in design education are applying various techniques such as virtual reality, collaborative design, web-based technologies, shape semantics, computer modeling, or visualization to CAAD. The preliminary findings demonstrate that the continuity of same research subjects or groups presents the research interests during the time span. Therefore, the relationships between time, subjects, and researchers are considered key attributes for association in data mining. Meanwhile, references are also important sources for research in addition to the main text. From the searches, we can detect the important references that continuously appear in certain research domains. For instance, there are 569 references abstracted from 56 papers in 2001. However, 19 references are overlapped and quoted by different researchers.

4.3. USER RESPONSE

We have found that different users are interested in different features in the uses of i-CAADRIA. From the user points of view, their searches are driven for different purposes such as: (1) search for definition and applications, (2) search for the researchers and their affiliation, and (3) search for references.

Meanwhile, the search behaviors can be distinguished by their research experience. Young researchers may search to gain further understanding of the fields, while experienced researchers tend to search for specific interests by ad hoc manners.

5. Conclusion

We have constructed the online research archive, i-CAADRIA, and collect 6-year conference papers. The findings in this study include the research patterns and data-mining techniques. While the dataset is small, some research patterns are revealed. Associative reasoning is useful for searching key information from the user point of views, while different user behaviors exist. This study suggests that smart web query and user interface can enhance our understanding of the research patterns and approaches. These findings provide the foundation for future development.

Furthermore, architecture research as well as design involves a large-volume data management activity. Therefore, an association-based information management mechanism is needed for research. Our future works is implementing the data mining techniques applied in i-CAADRIA to support distributed research or design collaboration.

Acknowledgements

The authors are grateful for the provision of proceedings from the previous conference organizers in the last six CAADRIA host institutions (1996 HKU, 1997 NCTU, 1998 Osaka U., 1999 TJU, 2000 NUS, 2001 USYD).

References

Chiang, Chua and Story: 2001, A smart web query method for semantic retrieval of web data, *Data & Knowledge Engingeering* 28, 63-84, Elsevier

Ciftcioglu, O. and Durmisevic, S.: 2001, Knowledge management by information mining, P*roceedings of CAAD Futures 2001*, Edinhoven, Netherlands, 533-545

CUMINCAD, url at http://itc.fgg.uni-lj.si/cumincad/

Inxight, url at http://www.inxight.com/

Martens, B. and Z. Turk: 1999, Working Experiences with a Cumulative Index on CAD: "CUMINCAD", *Proceedings of the eCAADe Conference*, Liverpool, UK, 327-333

THEBRAIN, url at http://www.thebrain.com/

Turk, Z., and B. Martens: 2001, The Topics of CAAD - A Machine's Perspective, *Proc. Of CAAD Futures 2001 Conference*, Edinhoven, Netherlands

Witten, I. H. and E. Frank: 2000, *Data Mining – Practical Machine Learning Tools and Techniques with JAVA Implementations*, Morgan Kaufmann

SOME PHENOMENA OF SPATIAL INTERACTION IN THE NETWORKED SPACES

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Abstract. As a result of the network-based nature of Internet and communications technologies, a new spatial form, which is defined as networked spaces by this research, is emerging. This paper provides a significant theoretical framework to unpack complex spatial relationships caused by the networked spaces. Such emerging design approach challenges the design thinking, design process and design knowledge of architecture, urban design, as well as media design.

1. Introduction

With the recent rapid development of information and communications technologies (ICTs), the influences of virtual world, generally called cyberspace, upon the physical world we live in have gradually increased. For example, Moss and Townsend (2000) indicates that information and telecommunications are changing many aspects of urban life, such as home, office, automobile, and street. The distributed nature of Internet also provides opportunities for connecting urban spaces to shape a new networked city. This new city form makes urban planning scholars to redefine the well-known concept of global city (Townsend, 2001). On the other hand, the virtual places existing in the cyberspace represent their own spatial knowledge, which is rather different from the physical ones (Liu, 2001; Huang, 2001a, 2001b). With respect to theory and design, architectural and urban theories and designs must include physical spaces, as well as virtual ones (Mitchell, 1999a). Furthermore, virtual places exist in a symbiotic relationship with physical cities to form a new urban typology by the advanced telecommunication links (Mitchell, 1999b; Warf, 2001). Therefore, a new spatial form which connects both physical and virtual

places is emergent, as a result of the network-based nature of Internet and communications technologies. This new spatial form is defined as networked spaces in this paper. However, such interrelated characteristics represent very complicated phenomena indeed. The complex linkages between space, place and information technology can be further understood by adopting a relational approach (Graham, 1998; Graham and Marvin, 2001). This perspective indicates social, cultural, political and economic construction or production of technologies within, as well as between specific places. Although this methodology is useful, further studies of the complex spatialities of virtual spaces are still crucial for the spatial-oriented disciplines, such as geography, urban design and architecture (Kitchin, 1998; Dodge and Kitchin, 2001). Moreover, communications technologies, such as telephone and Internet, are spatial in nature, which allow people to interact with each other from one specific space to the others. For instance, the major reason for construction of Internet was to build a decentralized computer network system linking remote military locations throughout the United States. Communications and interactions between distributed positions was the dominant concern of Internet. Recently, people have been increasingly used the Net for personal interaction and horizontal communication (Castells, 2000). As a consequence, the natures of Internet represent interaction between places and people. At the same time, the concept of networked spaces also indicates spatial interaction between different types of space. However, characteristics of such spatial interaction in the networked spaces are still unknown. How many phenomena of spatial interaction underlie the complex relationships between physical space and virtual space? And, what are the implications of spatial interaction for architects and urban designers? The objective of this study is to explore different types of the phenomena of spatial interaction in the networked spaces, and to examine their significances upon physical architecture and urban design.

This research is first to propose a theoretical framework for identifying the complex relationships between different spatial dimensions within the networked spaces, and to provide a conceptual model of spatial interaction. After that, in the light of the suggested framework, an ongoing design project of a digital museum in Hsinchu, Taiwan will be analyzed. Finally, this paper concludes by considering the implications, which are derived from the emerging phenomena of spatial interaction, for future design directions of architecture and urban environments.

2. A Theoretical Framework

There are two fundamental spatial dimensions mentioned in the previous review: physical space and virtual space. Owing to increasingly innovations of ICTs, virtual spaces are emerging in addition to physical spaces. This new

spatial dimension, which is generally called cyberspace, challenges the long-lasting design ideas of conventional architecture and urban design. It also provides many opportunities for architecture and urban designers to redefine design scope and to rethink spatial conceptions. These virtual spaces, such as Web space and cyber-city, have been regarded as the other layers attached onto the top of the physical ones (Kitchin, 1998; Shiode, 2000). Rather than emphasizing layers of different types of spaces, the theoretical framework of this paper focuses on different spatial combinations between physical and virtual spaces.

2.1. SPATIAL COMBINATIONS AND DIGITAL SPACE

It is to believe that both physical and virtual space can exist and develop independently. They possess their own objects, activities and spatial compositions. By implementing technologies of digital connection, such as Internet and World Wide Web (WWW), new spatial connections will arise from the mutual blending of the two spatial dimensions. For example, different physical spaces can be connected to each other by communication technology, such as the idea presented by networked city. The virtual cities also link to many virtual places by the objects within the cities. In addition, different virtual places may exchange their information through intelligent agents for satisfying user's requirements, such as specific information to be searched by user. Moreover, physical space and virtual space can coexist to form a new spatial dimension. For example, apart from constructing physical buildings around the world, Guggenheim Museum also wanted to build a digital museum on the cybersite. Therefore, this research categorizes three possible spatial combinations: physical space plus physical space, virtual space plus virtual space, and physical space plus virtual space. The resultant association of the two parallel-developed spaces is generally defined as digital space, because digitality is the major premise for the evolution and construction of the spatial concept, that is, networked spaces. Consequently, the conception of digital space consists of three distinctive types of networked spaces: physical networked space, virtual networked space, and co-existed space. The evolution and categorization of digitalized spatial concepts are summarized in Figure 1.

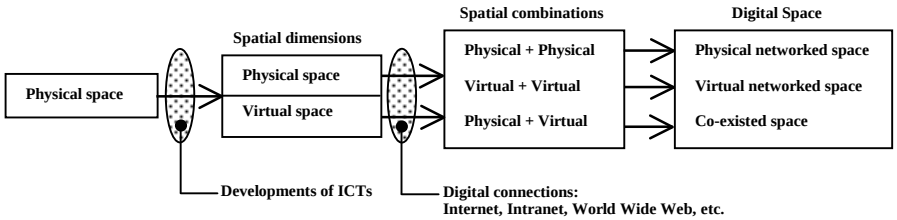


Figure 1: The evolution and categorization of digitalized spatial concepts.

2.2. DIGITALIZED SPATIAL INTERACTION

A new co-existed spatial form is emergent, as a result of the digital combination of physical and virtual space. As shown in Figure 2, the world we live in is composed of the physically and digitally connected spaces. On the other hand, virtual world, which presents its own web structure, might be seen as an extension of the physical world. Combination of both spatial dimensions and spatial interactions between them become possible by utilizing technologies of digital connection. For example, corporeal architecture, such as a library building, can build a virtual site on cyberspace in symbiotic with the real space. The virtual space is capable of linking to other sites for exchanging information that are provided by the co-existed physical ones. A new type of digital architectural form can eventually be constructed by applying such co-existed and co-built design methodology.

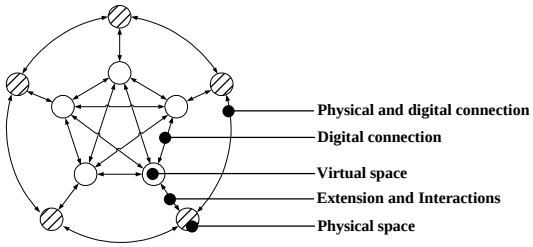


Figure 2: A conceptual model of spatial interaction.

As follows, some phenomena of spatial interaction derived from combination of the two spatial dimensions in the networked spaces will be described. First, in the physical space, people may interact with each other face-to-face or by using synchronous or asynchronous communications technologies, such as telephone and email. In the virtual space, people also use equivalent tools to that of physical space, such as avatar and chat room. Second, when people are online, they are interacting with the virtual space. Third, in the networked city, different spaces are linked together to present a space-to-space interaction. Forth, in the virtual world, different spaces may be connected together to form a large database system so that they can exchange information. Finally, when a physical space coexists with a virtual space, it is an interaction between two different spatial dimensions. Such arrangement includes all the phenomena of spatial interaction mentioned above. Therefore, this study identifies three phenomena of spatial interaction in the networked spaces: people-to-people, people-to-space, and space-to-space. In summary, the theoretical framework proposed by this paper consists of two components: the evolution and categorization of digitalized spatial concepts, and the spatial interaction model. Two concepts of the framework will apply to the analysis of the case study: digital space and

spatial interaction.

3. ITRI'S STEPS Digital Museum: A Case Study

The client of this project is Industrial Technology Research Institute (ITRI), that is the leading institution for developing technologies of High-Tech Industry in Taiwan. The purpose of this project is to build a digital museum (ITRI'S STEPS) which represents three primary objectives: to explain ITRI'S history and future visions, to promote technological aspects of education and recreation, and to integrate the developments of local research organizations such as Hsinchu Science-Based Industrial Park and National Chiao Tung University. However, in this project, we attempt to advocate three major design concepts: dual space, digital museum campus, and development of the digital city.

3.1. DUAL SPACE

In addition to design a physical digital museum in the campus space, we intend to construct a virtual museum in cyberspace (Figure 3). With respect to design, development of both museums is based on raw materials of ITRI such as texts and pictures, and follows the five exhibition themes: Taiwan Digitalized, Taiwan Lightened, Taiwan Energized, Taiwan the Life, and Vision of Taiwan. The concept of dual space also implies digital spatial interactions between the two types of museum, and the virtual one will connect to other cybersites. In other words, ITRI'S STEPS embodies two categories of the digital networked space: virtual networked space and co-existed space. Moreover, these two kinds of digital space give explanation of two interaction phenomena: space-to-space and people-to-space.

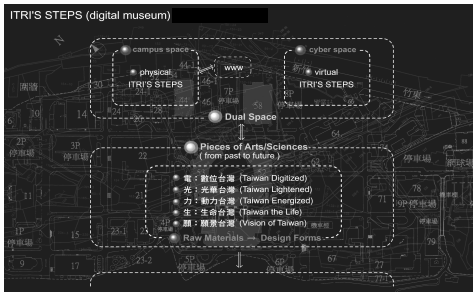


Figure 3: The design concept of dual space.

3.2. DIGITAL MUSEUM CAMPUS

ITRI'S STEPS has been regarded as the focus of the institution. By employing the latest telecommunications technologies, the museum links to other main buildings of the campus (Figure 4). Exhibition contents and

information will be transmitted into the lobbies of the buildings by installing relevant interface media. The lobbies will also be converted into informational spaces. Consequently, a new digital spatial form, which is a physical plus physical spatial combination, is created, namely, physical networked space. This type of digital space represents the third phenomenon of spatial interaction: space-to-space.

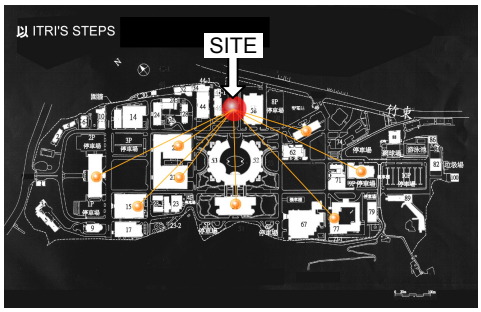


Figure 4: *The design concept of digital museum campus.*

3.3. DEVELOPMENT OF THE DIGITAL CITY

Since ITRI has been regarded as the center of technological innovations in Taiwan, ITRI'S STEPS is seen as the pivot in the development of Hsinchu digital city. Figure 5 depicts the framework and vision of the city. The concept of Hsinchu digital city, which consisted of Hsinchu City only, has already proposed by Peter Eisenman within the project, Hsinchu Digital Art Museum, in 2000. In order to intensify the influence of ITRI'S STEPS on a regional scale, we attempt to integrate Hsinchu County into the scope of this project. Therefore, the site of ITRI'S STEPS digitally connects to many distributed locations within both Hsinchu City and Hsinchu County. However, this design idea exemplifies all types of spatial combination, spatial interaction models, and the three categories of digital space: physical networked space, virtual networked space, and co-existed space.

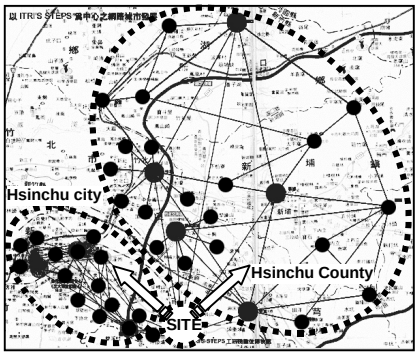


Figure 5: The design concept of development of the digital city.

4. Conclusions and Future Studies

The purpose of this paper attempts to investigate the emerging phenomena of spatial interaction in the networked spaces. This study proposes a theoretical framework that is comprised of two components: the evolution and categorization of digitalized spatial concepts, and a conceptual model of spatial interaction. The concept of digital space and spatial interaction model of the framework have been applied to the analysis of the case study: ITRI'S STEPS digital museum. One of the major results of this research is that three phenomena of spatial interaction have been identified: people-to-people, people-to-space, and space-to-space. All of which bring into being from the complex relationships of digital networked spaces. In addition, the theoretical framework also reveals complexity of space design in this digital age. Architects and urban designers already encounter the very complicated digital connections. They may take advantage of digital technologies for conducting their designs. The proposed framework of this paper is significant to them for clarifying different categories of digital space while designing. These findings indicate several implications for architecture and urban design. First, the dimension of space design can be extended further from real world to the virtual world, or diverse combinations of them. Most importantly, the phenomena of spatial interaction support the extension. In other words, new spaces and new activities might be resulted from spatial interactions in the networked spaces.

Second, a number of spatial combinations also extend the interactive dimension between architecture and media. For example, the properties of digital networked spaces suggested by this paper are different from the concepts of recombinant architecture (Mitchell, 1995) and recombinant design (Horan, 2000) in the relations between architecture and media. There are two relations between them: architecture in media, and media in architecture (Rijken, 1999). On the one hand, characteristics of physical space may be either mapped or transformed into virtual world, such as websites. Architecture, accordingly, becomes metaphors for media designers to carry out design of virtual environments. We may consider this phenomenon as architecture in media. On the other hand, on the contrary, the virtual world may be incorporated into physical space. This inclusion of the hardware aspects of virtual world can be regarded as media in architecture. Obviously, components of digital space not only encompass all relationships mentioned above, but also create a new domain, that is, spatial interaction, between architecture and media.

Third, spatial characteristics are being digitalized. This phenomenon is the key for future design directions and design professions. They have gradually impacted by digitality-mediated spatial characteristics in three fundamental features: design process, interactions between members of the design team, and relations between architecture and media become more

important than ever. Finally, in this digitality-mediated age, architects and urban designers consider space design not only including the corporeal spaces, but also the media in the digital space. Such emerging design approach challenges the design thinking and design knowledge of architects, urban designers, as well as media designers. However, this paper is only a preliminary study. Relations between different phenomena of spatial interaction have not examined yet. In addition, relations between spatial interaction and media are still unknown. Future studies will first to further explore the mechanism underlying the spatial interaction. Then, the focus will aim to the intervention of spatial interaction between architecture and media. Accordingly, it would be possible to add more understandings to the study of influences of communications technologies upon architecture and urban design.

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References

Castells, M.: 2000, Grassrooting the space of flows, in Wheeler, J. O., Aoyama, Y., and Barney, W. (eds.), Cities in the telecommunications age: the fracturing of geographies, Routledge, London, pp. 18-27.

Dodge, M. and Kitchin, R. M.: 2001, Mapping Cyberspace, Routledge, London.

Graham, S.: 1998, The end of geography or the explosion of place? Conceptualizing space, place and information technology, Progress in Human Geography, 22/2, pp. 165-185.

Graham, S. and Marvin, S.: 2001, Splintering urbanism: networked infrastructures, technological mobilities and the urban condition, Routledge, London.

Horan, T. A.: 2000, A new civic architecture: bringing electronic space to public space, Journal of Urban Technology, Vol. 7, Number 2, pp. 59-83.

Huang, C. H.: 2001a, A preliminary study of spatializing cyberspace, in Gero, J. S., Chase, S. and Rosenman, M. (eds), CAADRIA2001, Key Centre of Design Computing and Cognition, University of Sydney, Australia, pp. 27-37.

Huang, C. H.: 2001b, A preliminary study of spatializing cyberspace: A cognitive approach, in Penttilä, H. (ed.), ECAADE2001, Department of Architecture, Helsinki University of Technology, Finland, pp. 511-516.

Kitchin, R. M.: 1998, Towards geographies of cyberspace, Progress in Human Geography, 22/3, pp. 385-406.

Liu, Y. T.: 2001, Spatial representation of design thinking in virtual space, in J. S. Gero and B. Tversky (eds.), Visual and Spatial Reasoning in Design II, Key Centre of Design Computing and Cognition, University of Sydney, Australia, pp. 25-40.

Mitchell, W. J.: 1995, City of Bits, MIT Press, Cambridge, MA.

Mitchell, W. J.: 1999a, e-topia: urban life, Jim-but not as we know it, MIT Press, Cambridge,

MA.

Mitchell, W. J.: 1999b, The city of bits hypothesis, in D. A. Schön, B. Sanyal and W. J. Mitchell (eds), High Technology and Low-income Communities: Prospects for the Positive Use of Advanced Information Technology, MIT Press, Cambridge, MA, pp. 105-129.

Moss, M. L. and Townsend, A. M.: 2000, How telecommunications systems are transforming urban spaces, in Wheeler, J. O., Aoyama, Y., and Barney, W. (eds.), Cities in the telecommunications age: the fracturing of geographies, Routledge, London, pp. 31-41.

Rijken, D.: 1999, Information in space: explorations in media and architecture, Interactions, May + June, pp. 44-57.

Shiode, N.: 2000, Urban planning, information technology, and cyberspace, Journal of Urban Technology, vol. 7, number 2, pp. 105-126.

Townsend, A. M.: 2001, The Internet and the rise of the new network cities, 1969-1999, Environment and Planning B: Planning and Design, vol. 28, pp. 39-58.

Warf, B.: 2001, Segueways into cyberspace: multiple geographies of the digital divide, Environment and Planning B: Planning and Design, vol. 28, pp. 3-19.

XML SCHEMA FOR INVESTIGATIONS OF POLISH TRADITIONAL RURAL ARCHITECTURE

The Development Process

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Abstract. The XML is a perfect tool for scientific data management and analyses, because of its potential as a language for representation of structured graphical information stored in object-relational databases. The paper discusses the development process of the architectural database, defined by the XML Schema definitions (RuralXML). The database is being created in order to describe Polish traditional rural architecture for scientific investigations of architectural, rural and spatial planning fields.

1. The Objective

The first objective of the work was to create a tool for structuralization of existing rich architectural data, collected during the Student Summer Workshops of Bialystok University of Technology, Faculty of Architecture since 1986. Now we own over 600 kg (!) of the high-quality photos and paper drawings – which contain plans, elevations and sections of hundreds of buildings of the North-East Polish rural areas, about 30 detailed large-format plans of villages with hundreds of additional draftings (street sections, panoramas, filled in questionnaires) and text data (describing land and building properties). This huge mass of paper documents, although containing valuable information, was unused because of its amount and lack of proper classification and storage methods. XML enables us easily structure this information after it's digitizing, and then to store it on digital media.

Now we intend to work out a technology which enables us to create and maintain an XML-based, open database of not only local architecture, but all Polish regional architecture, optimized for investigations of architectural and

spatial planning fields. For this we developed a working methodology, allowing effective notation of hybrid data.

These works are in progress now. The database is being developed, and based on the XML schema called RuralXML. RuralXML is going to be the key technology to succeed this work. In the future the database will be distributed on CD's and through the Internet.

2. The Advantages of XML Notation

XML can help with storage, integration, assessment and fast digitization of very large tree-like data structures containing heterogeneous information used in scientific investigation. We decided to design database structure first and then to link it by XML syntax because of the above and the following reasons (Loudon, 2000; Barillot and Achard, 2000; van Leeuven and Jessurun, 2001):

1) It allows meaningful, content-oriented data notation, providing means for building many hierarchies for the data.
2) It allows efficient processing of semi-structural data.
3) Its semantics consists of simple rules, is easy to learn and to implement.
4) It gives methods and tools for development of meaningful data standards.
5) XML is a widely adopted standard, and is popular especially in IT world – it has became the key technology in some PDM applications.
6) XML is being implemented in CAD software and (through interfaces) in some commercial databases.
7) Both data structure and data itself can be written in ASCII text files or linked to ASCII files. Every text editor can be used to modify these files.
8) There are many XML parsers in existence which can validate XML documents, so XML Schema and parsers can be easily used for checking database consistency.
9) Its metadata concept makes it possible to display a great number of various data efficiently, even if using popular web browsers.
10) It can provide a consistent user interface, mediating among the various retrieval systems.
11) Data syntax, data itself, and display methods can be independently defined, exchanged and stored in different documents.
12) XML notation is platform-independent and it increases data compatibility with other data sets and with external software.
13) Data notation based on Unicode standard makes it language-independent.

3. The Input Data

The data sets are expected to be flexible and structuralized in many ways, so it is important to build architectural databases according to many case-specific data layouts. That is why both the input data structure and the database itself have to be well organized unless the final database's usage is unnecessarily limited. The optimization process of input data included the following phases: (1) Resources Analysis, (2) Data Aggregation, (3) Classification, and (4) the Final Input Data Model Construction.

3.1. THE INFORMATION RESOURCES

First the conceptual input data model was created. This model reflected the existing paper document resources (owned by the Faculty) such as:

1) 30 plans of villages with associated attribute information (composition and parameters of sites and buildings, construction and materials, dates),
2) Several hundreds of detailed draftings of sites with many additional data,
3) Several hundreds of buildings' technical draftings: plans, elevations, sections,
4) Several thousands of pencil sketches,
5) Several hundreds of photos,
6) About 400 revival plans of villages and remodeling projects of rural sites,
7) More than 500 small student's projects concerning regional architecture,
8) Many draftings, sketches and photos of building traditional details,
9) Bibliography (indicative resources),
10) Relative texts and citations.

These are the existing documents gathered by the Faculty until now. It is possible that other organizations (educational, scientific or governmental) will follow the investigation and add their data to the database. For this reason the group called 'Other' was added to the conceptual data model.

The author has also linked his private collection of demographic digital data in to the conceptual data model. This data shows the strong depopulation processes occurring in the Northeast areas of Poland. The data that concerns 1513 villages with difficult economics is especially detailed.

3.2. DATA AGGREGATION

Then the virtual data model was built. This was also the input model but reshaped in order to avoid large data redundancy. After the 'data extraction' (from the existing archival documents) all the pieces of information were basically classified and aggregated into groups according to their role in architectural and spatial analyses.

3.3. WORKING CLASSIFICATIONS

The process of preparing the final information model included the proper classifications of input data, according to data types (vector-2D-drafting, vector-2D-map, vector-3D, raster-map, raster-scan, raster-photo, text-attribute, text-citation, text-indicative, numerical, link or some complex types), application fields (architectural-modeling, architectural-comparative, architectural-detailing, rural-statistical, spatial planning, social-demographic), data generic usage (modeling, CAD, GIS, illustrative) and data extraction (querying, browsing, accessing as link targets from main indexes, surfing the hyper structures).

There were some conclusions made after the classification process:

1) Input data classification according to data types will be important in managing data and should influence the database structure.
2) Classification according to application fields will be important mainly when accessing data from the source, so it can have some influence on the information structure, and it also determines the interface.
3) Data generic usage affects the methods of visualization and is data-sensitive in some cases, but there is no need to make this factor competitive with the first classification factor (according to data types). This is not essential unless there are problems with data viewers.
4) Data extraction methods are important for both, data structure and interface. All data access methods should be well recognized before shaping data structure.

3.4. THE FINAL INPUT DATA MODEL

The Final Input Data Model (FIDM) was created as a foundation for XML-based data notation represented by RuralXML Schema. FIDM has been optimized until now and is still under development. It consists of over 500 simple and complex data types, organized into 10 tree-like groups: (1) Settlement, (2) Village, (3) Public Space, (4) Public Object, (5) Site, (6) Building, (7) Small Object, (8) Detail, (9) Garden, and (10) Literature. Each group contains three levels of sub-groups. For instance the fifth group, 'Site', has 10 sub-groups on the first level. They are: ID, Input_Date, Name (sub-sets: Street/Number), Geometry (sub-sets: Area/Length/Width/ShapeFactor), Neighbourhood (sub-sets: Sites/Communication/RelativePosition /Absolute), Internal Communication (sub-sets: SiteType/Entries/AccessType), Buildings (NumberOf/ Houses/OtherBuildings/Occupancy/Area), Functions (Number/ F_Type/Collisions/Zones/Sub-zones), and Adequacy (InvestmentNeeds/ DivisionNeeds/LinkageNeeds/ModificationNeeds). All the sub-groups can consist of smaller sub-groups or atoms, and they can refer to other groups at

any level (for example the sixth group, 'Building', can refer to sixth subgroup in the fifth group, 'Site->Buildings').

4. The Main Data Structure

The Main Data Structure (MDS) had been worked out upon the FIDM base. This was then implemented in the XML Schema. To get the MDS, the FIDM was reordered as follows:

1) The main FIDM tree-like data structures were linked.
2) Redundant elements were unified and hyperlinked.
3) Dependencies were tracked and all elements were redefined as child-elements or other elements' attributes.
4) All atomic elements and attributes were analyzed carefully and optimized.
5) Data types were specified according to data usage.
6) Elements' identifiers were reassigned according to new data structure.
7) Data handling processes were analyzed using the MDS structure.

The goals of creating the main data structure were:

- to provide the unified data composition optimized for data browsing,
- to optimize the elements' linkage (the MDS hyperlink structuralization allowed us to avoid the FIDM data redundancy),
- to test and check the access to data.

Now the MDS is under development as an independent contribution to other fields, too.

5. The XML Schema

XML technology offers many advantages for interchanging data. The Document Type Definitions (DTD) can describe the syntax and structure of XML data sets, but it has many limitations that makes it not an elegant tool for defining document content. Therefore we have chosen the concurrent XML Schema for data standardization. Before the implementing the MDS as a XML structure, we analyzed the existing AEC data notations in commercial software, and we found these notations not suited well our specific needs. But we accepted some commercial concepts, which allow us to create not static, but flexible semi-structured data using XML syntax (the examples are 'Link elements' in DesigXML and implementation of *IfcProxies* in IfcXML).

We found several other interesting ideas in papers written by Lan and Jeng (2001), Shanmugasundaram, Shekita, Barr, Carey, Lindsay, Pirahesh and Reinwald (2001), Stouffs and Krishnamur (2000), and Tunçer and

Stouffs (2000). These works ensured us that XML syntax based on rigidly structured schemas could be an efficient way of organizing the research heterogeneous data.

The final RuralXML Schema, describing the MDS data content, is now under development. The differences between FIDM, MDS and the XML Schema are shown in the following table:

TABLE 1. Comparing the FIDM, MDS and the XML Schema

	FIDM	MDS	XML Schema
The goal:	Providing fast data input (it was the 'temporary data interface' between source data and XML database)	Optimising collected data, preparing for implementation	Finally implemented data, optimised for data access (output-specific)
Main classification factors:	According to source content mainly, and to application fields	According to source content, data usage, and data types	According to source content, data types and extraction methods
Data structure:	Multi-tree-like, significantly redundant	Tree-like, unified, with some redundancy	Tree-like, unified, with small redundancy
Data types:	Open, unspecified	Fixed, specified	Generally specified, but flexible
State:	Done	In this case done, but some changes possible. It is under development for other applications	Work in progress

There are some areas of interest, which are taken into consideration and can influence the final RuralXML Schema. These are:

A. Addition of both, simple query language and keyword searching capabilities to the RuralXML-based database.
B. Optimization of data extraction methods with external software.
C. Implementation of query language allowing writing queries that construct new XML documents from the main database.
D. Investigation into applying XML-based syntax to data management (XLL, Xlink, Xpointer, XSLT, XSL-FO)

6. The Interface

XML syntax can be used to represent both, structured data (in this case records in bibliography database or items in building databases) and unstructured data (text, unstructured graphical information). For that reason it is important to have tools that can select records from the structured database (XML query language) and search for information in text (keyword search). Several of these tools were developed or analyzed by Badard and Richard (2001), Deutsch, Fernandez, Florescu, Levyd and Suciu (1999), Florescu, Kossmann and Manolescu (2000), and Houlding (2001).

These tools will be implemented in the future. Now the simpler methods based on XML syntax are being developed.

Problems with access to application-specific data (GIS, CAD, raster) are taken under consideration, too. Of course there are plenty of viewers accessible, but our objective is to choose the simplest, but the most powerful software. For example some CAD viewers can be unified with web browsers, so users can work with the data without leaving a browser. Now the database is working with the AutoCAD files, and graphical information is stored generally in two groups of formats: vector AutoCAD-based (DWG, DWF with tendency to migrate to XML-based SVG format) and popular raster formats, such as JPG and GIF (and sometimes monochrome BMP).

In the future we are going to build a stand-alone piece of software optimized for processing and displaying our XML-notated data.

7. Conclusions

Software vendors and standard organizations all over the world have recognized the potential of XML notations for CAD data. Many corporations and standard bodies are developing XML-based notations of CAD data, focusing on interoperability problems. Some of these notations are becoming standards (aecXML, *i-drop*), influencing the development of all CAAD industry. The analysis of the applicability of the commercial standards to scientific databases showed, that they are not efficient in use.

Investigating the XML usage in scientific data notation, we found that the key problem is structuralization data before describing them by XML syntax. Commercial, architectural XML standards (such as aecXML, ifcXML, RedlineXML and DesignXML) need structural data, organized according to dialect-specific conventions. In many cases the data layout can be good for cost-working applications, but not for architectural ones, and especially not for scientific databases. All these existing notations did not suite our needs. We had to rebuild data sets many times in order to have optimized metadata ready for implementation in a database. The optimization process is our contribution to the field of rural planning, because some data structures (especially the MDS) can be applicable to experimental, scientific and educational use.

Both, XML schema and data structures are being developed until now and the result will be an architectural database stored on CD’s and distributed for educational and scientific purposes. This first stage of the work will be finished in December 2002.

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References

Badard T. and Richard D.: 2001, Using XML for the exchange of updating information between geographical information systems, *Computers, Environment and Urban Systems*, 25, 17-31.

Barillot, E. and Achard, F.: 2000, XML: a lingua franca for science? in *TIBTECH*, 8(18) pp. 331-333

Deutsch A., Fernandez M., Florescu D., Levyd A. and Suciu D.: 1999, A query language for XML, *Computer Networks,* 31, 1155–1169.

Florescu D., Kossmann D. and Manolescu I.: 2000, Integrating keyword search into XML query processing. *Computer Networks,* 33, 119-135.

Houlding S.W.: 2001, XML - an opportunity for <meaningful> data standards in the geosciences, *Computers & Geosciences,* 27, 839–849.

Lan J. and Jeng T.: 2001, Enhancing Shared Understanding in Collaborative Design Communication: an XML approach, in *CAADRIA'01: Proceedings of the Sixth Conference on Computer Aided Architectural Design Research in Asia*, Sydney, pp. 285-289.

Loudon, T.V.: 2000, Geoscience after IT. Adjusting the emerging information system to new Technology, in *Computers & Geosciences,* 26, A109-A121.

Shanmugasundaram J., Shekita E., Barr R., Carey M., Lindsay B., Pirahesh H. and Reinwald B.: 2001, Efficiently publishing relational data as XML documents, in *The VLDB Journal*, 10, 133 –154.

Stouffs R. and Krishnamur R.: 2000, Alternative Computational Design Representations, in *4th SIGRADI Conference Proceedings,* Rio de Janeiro, pp. 200-202.

Szewczyk J.: 2001, Engineering Portals: Networked Architectural Information Management, in *19th eCAADe Conference on Architectural Information Management*, (ed. Hannu Penttilä), HUT, Helsinki, pp. 150-155.

Tunçer B. and Stouffs R.: 2000, A Representational Framework for Architectural Analysis. in *4th SIGRADI Conference Proceedings,* Rio de Janeiro, pp. 206-208

van Leeuven J.P. and Jessurun A.J.: 2001a, XML for Flexibility and Extensibility of Design Information Models, in *CAADRIA'01: Proceedings of the Sixth Conference on Computer Aided Architectural Design Research in Asia*, Sydney, pp. 491-501.

ONE CITY TO GO

A multi-modal approach to delivering city data

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Abstract. The work described here is aimed at developing city models, with underlying data, in such a way that the model and data can be accessed quickly and efficiently. A particular outcome of our approach to the work is that the model and associated data can be accessed through a palmtop device. This degree of portability opens up a range of opportunities to access this important information; the kind of information related to city models and associated data that is expanding daily.

1. Context

In the past mobile city information systems, without 3D graphic capability have been developed such as CitiKey [1] and Citysync [2]. Equally some - very effective net-accessible city information systems with 3D representation have been developed such as Virtual Glasgow (Maver, 1996; Maver *et al*, 2000) [3] and Virtual Cheltenham [4]. Over the past few years there has been experimentation and development of mobile city guides with 3D capability such as those described by Raposo *et al* (1997) and Belz *et al* (1998). One project of interest in particular is the Deep Map project (Coors and Wiedmann, 1998) that will embody 3D worlds in a mobile environment

[5]. Also of interest is the CyPhone project that aims to create visions of the future UMTS devices [6]. More recently Rakkolainen *et al* (2001) have developed their system to visualize real-time Global Positioning System (GPS) data through VRML worlds. Our work parallels and augments such recent developments, and does this by integration of associated digital technologies.

2. Accessibility

Many of the current web implementations of three-dimensional models require specialised browser plug-ins and are slow to access. Although VRML and other more specialised plug-ins provide a high level of functionality they have a small installed user base outside the CAAD and product design fields. We believe that at present this limits their usefulness, as functionality does not exist for the user if that functionality is not usable.

Much of our recent research has focused on using readily available, low-cost and generic technology to provide access to virtual worlds and 3D models at a city wide and building specific level (Knight and Brown, 1999). This new strand of the research applies the same strategy to providing access to three-dimensional city models and underlying information about cities and buildings over the Internet. We believe that this approach will make the data accessible to a greater number of users thus helping to support the urban planning process and facilitating end user consultation.

One initial programme of the research has focused on presenting information on significant buildings in Liverpool over the Internet using a number of different technologies [7]. At the core of this work is a three-dimensional city model and a web-based database that provides the content for the site. At present the database contains thirty-five buildings the data for which is split into 24 fields.

The database content is interfaced over the web in four ways; server generated web pages, interactive multimedia city architecture tours, PDA based tours and a ‘city navigator’.

3. The database methodology

A recent report by researchers at the University of California at Berkeley estimated that at the end of the year 2000 there were 2.1 billion static web pages accessible over the Internet with an additional 7.3 million pages being added every day (Lyman and Varian, 2000). Although Odlyzko (2000) advises us to be cautious of the huge growth statistics quoted in this field it is undoubtable that Internet growth rates are substantial.

Whilst it is clear that the Internet offers a huge mass of data it is widely accepted that many pages are of a reduced value as they are seldom or never updated. In order to improve the efficiency of the update process many sites store much of their content in a centralised database often allowing updates to be administered without knowledge of HTML. This database methodology has the added advantage of allowing data to be used multiple times throughout a site without the need for dual keying. This provides developers with the possibility of allowing wide-ranging access to up to date information in a variety of contexts. The multi-modal approach of this project benefits from this.

4. Server generated pages

When a user accesses a database driven web page the content is extracted from the database and added to the page by a server based script before it is sent to the user's browser. This approach forms the most basic method of accessing the Liverpool Architecture database. When a building is selected via a web-based form the HTML page that is displayed shows building data taken from the database.

The present HTML form uses a simple pull-down menu that lists each of the buildings in the database. The menu is generated from the database so when additional buildings are added they are automatically included in the pull-down menu. As the database expands the form will be modified to allow a more complex search of the data.

5. Interactive Multimedia tours

The second application of the data is in the form of two animated architectural tours of the city. While the web-based form allows individual building data to be accessed the tours provide a useful structure for accessing a group of buildings. At present the two available tours are based on the geographic proximity of buildings and cover the east and west business districts of the city. These routes are based on initial research carried out by the Liverpool Architecture Society.

The animated tours use a pseudo 3D model of parts of the city to show buildings in their context, making them easier to locate. The model provides users with an overall plan of the city with landmark and featured buildings modelled using simple primitives. The highly refined nature of the model drastically reduces end user download times but still provides enough data to show how each building sits within the overall cityscape. In addition to the model the tours use images and text based information from the underlying

database. This combination of a simple virtual model with supplementary photographic images provides users with a good level of contextual information whilst minimising access times.

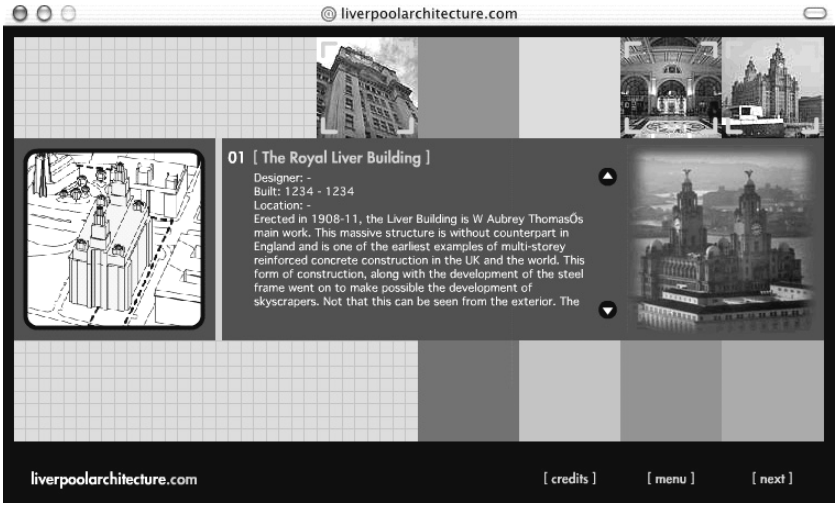


Figure 1. The tour interface showing the Royal Liver Building.

Many online tours use either linked HTML pages or VRML models whereas the two prototype Liverpool tours use Macromedia Flash technology (figure 1). This approach was chosen as it enabled simple animation of the 3D model using cross-platform technology that has a high installed user base outside design disciplines. The animation is limited to a predefined route that progresses from building to building as users navigate the tour.

6. Palm based tours

The third strand of the project is the customisation of the tours for mobile users. The work aims to exploit existing handheld computing technology and has focused on allowing access via a Palmtop device so that users can view the information as they do the physical tour.

Our Palmtop prototype (figure 2) allows access to the building database remotely (on site) via a web enabled PDA and this is being implemented currently. However, our work to date has concentrated on pre-installing the data for later off-line viewing (whilst on site). This results in a stand-alone portable system that has performance benefits, as it does not rely on wireless networking. It is, however, limited as it does not allow dynamic interaction with the database on location (Davies *et al*, 1998).

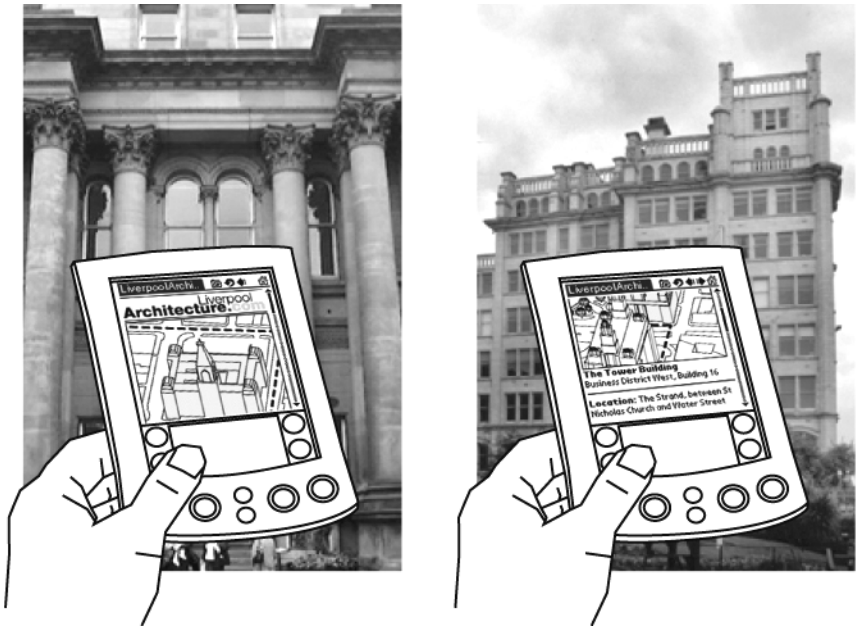


Figure 2. The PDA-based mobile tours

In order to allow a large number of users to easily access the data on a Palmtop the building data is viewed using AvantGo [8]. This software is now installed as standard on many PDAs and was selected for prototype development because of the project's emphasis on using low-cost/generic technology. AvantGo runs on the Palmtop and acts as a protocol gateway between the PDA and the HTML output from the web server hosting the database (Herstad, Van Thanh and Kristoffersen, 1998).

On the prototype when the database content is downloaded to a PDA it follows the specification stored by a default user profile on the web server. The default profile allows users to access both the east and west business district tours, with each building represented by a simple 3D model image, text description and directions. The enhanced prototype will allow users to define their own custom profile, enabling them to select the building data they wish to download thus creating customised Architectural tours of the city. These custom tours may, like the present ones, be based on the geographic proximity of buildings but users will also be able to search the database and build tours around other criteria such as building types, architects and periods of time.

7. The City Navigator

The fourth component of the project is the city navigator, which is concerned with applying a three-dimensional model to improve the usability of data. The objectives of this aspect of the work are to enable users to find out both *what* a building is and *where* a building is.

The system uses a small window to display an easily understood pseudo 3D model of the city. Only a portion of the model can be viewed on screen at any one time but users can freely navigate around, selecting buildings to access their database entry. When a user moves the cursor over a building basic data relating to that building is displayed, when a user clicks on a building the full database entry is displayed.

Landmarks provide key visual cues when wayfinding and it has been shown that 3D models help users to recognise landmarks and find a route in cities easier than symbolic 2D maps (Rakkolainen et al, 2001). The second objective of this strand of our work is to enable users to locate a known building within the city using the 3D computer visualisation for navigation support. To achieve this the city navigator combines the use of both the model and a HTML form to interface with the underlying database.

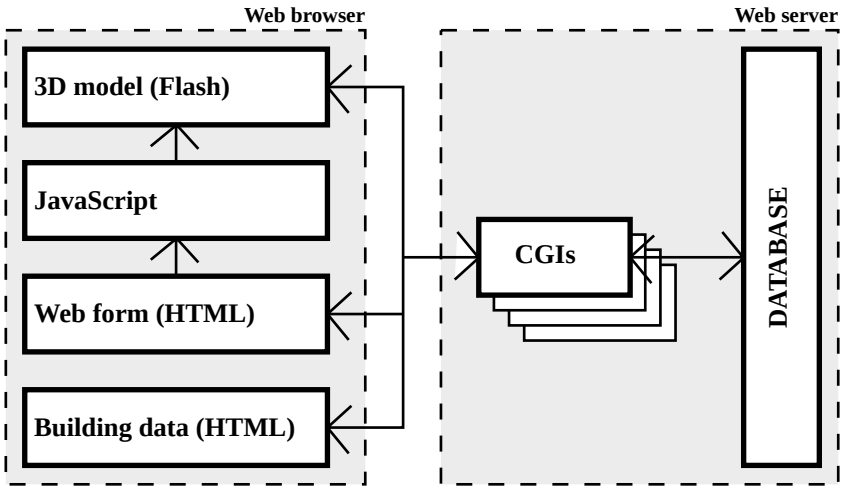


Figure 3. The city navigator system overview

When a user selects the building they wish to locate using the HTML form, the system visualises the query results by automatically navigating the model until the required building and its immediate environment are visible. The building's full database entry is also displayed using images and text.

The prototype city navigator uses HTML and Macromedia Flash technology and is accessible via a web browser. Communication between

the various elements of the system uses CGI and JavaScript protocols (figure 3).

8. Future developments

Our initial multi-modal implementation of the database approach allows users to access historical and architectural information on buildings in Liverpool using widely available and appropriate technology. The incorporation of the pseudo 3D model into the various systems adds value by both making the data more accessible and improving wayfinding.

We are currently working to adapt the techniques in order to improve access to other types of city and building data. One of these pilot projects will focus on developing the city navigator for use as a web-based way-finding aid for visitors to the University of Liverpool campus.

We are also working with a number of local and regional organisations. The aim here is to modify the techniques in order to provide an effective tool to aid strategic city development, and in this regard the current implementation shows great potential.

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References

Belz, C., Jung, H., Santos, L., Strack, R., and Latva-Rasku, P.: 1998, Handling of Dynamic 2D/3-D Graphics in Narrow-Band Mobile Services, *in Virtual Worlds on the Internet*, IEEE Computer Society, p147-156.

Coors, V. and Wiedmann, B.: 1998, Using Wearable GIS in outdoor applications, *in Proceedings of the Symposium on Interactive Applications for Mobile Computing*, IMC'98, Rostock, Germany, November 1998, http://www.egd.igd.fhg.de/~imc98/ Proceedings/imc98-SessionMA4-1.pdf

Davies, N., Mitchell, K., Cheverst, K. and Blair, G.: 1998, Developing a context sensitive tourist guide, *in Proceedings of the First Workshop on Human Computer Interaction for Mobile Devices*, Glasgow, Scotland, May 1998,

http://www.des.gla.ac.uk/~johnson/papers/mobile/HCIMD1.html

Herstad, J., Van Thanh, D. and Kristoffersen, S.: 1998, Wireless Markup Language as a framework for interaction with Mobile Communication Devices, *in Proceedings of the First Workshop on Human Computer Interaction for Mobile Devices*, Glasgow, Scotland, May 1998, http://www.des.gla.ac.uk/~johnson/papers/mobile/HCIMD1.html

Knight, M. and Brown, A.: 1999, Working with Virtual environments through appropriate

physical interfaces, *in* Brown, A., Knight, M. and Berridge, P. (eds), *Architectural Computing: From Turing to 2000*, University of Liverpool, September 1999, p431-436

Lyman, P. and Varian, H. R.: 2000, *How much information*, School of Management and System, University of California at Berkeley, http://www.sims.berkeley.edu/how-much-info/

Maver, T. W.: 1996, The Virtual City*, in Proceedings of CAD & Creativeness*, Bialystock, Poland, 25-27 April 1996, pp. 181-184

Maver, T., Petric, J., Ennis, G. and Lindsay, M.: 2000, Visiting The Virtual City, *in Proceedings of SIGraDi'2000 - Construindo (n)o espacio digital (constructing the digital Space)*, Rio de Janeiro, Brazil, 25-28 September 2000, pp. 135-139

Odlyzko, A.: 2000, Internet growth: myth and reality, use and abuse, *in iMP: Information Impacts Magazine*, November 2000,

http://www.cisp.org/imp/november_2000/odlyzko/11_00odlyzko.htm

Rakkolainen, I., Vainio, T., Kupila, H., Majahalme, T. and Salmenpera, H.: 2001, A GPS-based 3D City Info for Mobile Users, *in Proceedings of SCI 2001 conference*, Orlando, USA, August 2001. http://www.uta.fi/hyper/projektit/tred/

Raposo, A., Neumann, Magalhães, L., and Ricarte,I.: 1997 Visualization in a Mobile WWW Environment, *in Proceedings of WebNet 97 - World Conference of the WWW, Internet and Intranet*, November 1997.

Web references:

[1] CitiKey software, http://www.CitiKey.com/

[2] CitySync, http://www.citysync.com/

[3] The Glasgow VRML model, http://iris.abacus.strath.ac.uk/glasgow/

[4] Virtual Cheltenham, http://www.ralphski.co.uk/3nge/

[5] Deep Map project,

http://www.eml.villabosch.de/deutsch/Forschung/deepmap/deepmap.html

[6] CyPhone project, http://www.ee.oulu.fi/~tino/pihvi.html

[7] Liverpool Architecture project, http://www.liverpoolarchitecture.com

[8] AvantGo, http://www.avantgo.com

THE LIMITATIONS OF ARCHITECTURAL XML-POWERED DATABASES

Open Standards versus XML Glue

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Abstract. The paper deals with the limitations of architectural XML-powered databases, focusing on flexibility of data notations. Standard commercial notations are taken under consideration, to recognize XML potential in processing open, scientific architectural data.

1. The Problem

One of the most difficult problems in CAAD is a great variety of data notations. A great work is made to solve this problem: common standards for interoperability as well as vendor-specific ones were expecting to satisfy both software vendors and users. Autodesk had popularized DXF standard and in fact DWG, which then was promoted by OpenDWG Alliance. ISO has developed first IGES, then STEP, International Alliance for Interoperability has worked out IFC definitions, and also GDL language has became a well known standard for architectural notation, as a result of Graphisoft's efforts followed by GDL Alliance's and GDL Technology's activities.

These were only beginnings of world-wide standardization attempts. For the last three years some hundreds of vendors started to develop different XML schemas as panacea for interoperability problems. But the use of the old structural CAD notations, new object-oriented ones and even the latest XML-based architectural representations was limited until now. The existing technologies haven't been developed definitely (like aecXML, DesignXML) or theirs appliance is not satisfying yet (BLIS-XML, adpML, RedlineXML).

The basic limitation of these technologies is defining new data sets unforeseen in XML schemas, and processing complex data in flexible, open

context. This implies problems with creating XML-based architectural databases. The existing, fixed data sets are too complex, difficult to deal with, they are often inconsistent and in result they are not really oriented towards architecture. Architectural notations lack the architectural meaning.

2. The Outline of Architectural Databases

There were many attempts to reshape architectural data in order to get consist database for design, educational or scientific purposes. For example Gu and Xie (1998) describe a database composed of three types of libraries: specifications library, case library and "generative mode" library.

Architectural data are in fact a special example of hybrid metadata. The problems of managing hybrid data have been well recognized. For instance Loudon (2000) summarizes the investigations on digital data repositories and digital libraries. Interesting analysis of repositories are also made by others (Kahn and Wilensky, 1995; Arms, Blanchi and Overly, 1997).

The model of digital data repositories and digital libraries can be a good approximation of architectural database for scientific/educational purposes (but not for design). Arms, Blanchi and Overly (1997) recognize four main modules of digital libraries: user interfaces, repositories (a database can have many repositories of various types), a handle system used to identify resources, and an independent search system, based on query languages and keyword search capabilities. This modular approach can be acceptable for architectural databases, but we can add to this a data processor, i.e. CAD engine. In some cases, but not from user's point of view, a data processor can be perceived as a part of an interface. These four main database's elements are outlined below.

2.1. USER INTERFACES AND DATA PROCESSORS

Integration of CAD data structure and the user interface was recognized as an important aspect of engineering systems (Anumba, 1996). Arms, Blanchi and Overly (1997) suggest necessity of dual interface for digital libraries, i.e. one interface for users (data extraction) and the second one for managers (data processing). This can make sense in CAD scientific/educational databases. Common user interface problems in CAD are recognized in detail and divided into 24 groups by Jakimowicz and Szewczyk (2001).

Some interesting CAAD interface concepts follow by implementing XML-based technologies (like *i-drop*) in new commercial software, such as Autodesk Architectural Studio, especially if running as ASP programs in standard web browsers. Other concepts, significant for the subject matter, can be found in XML-based PDM applications, tightly integrated with

CAAD engines, or even in extranet CAD portals.

2.2. REPOSITORIES

Szykman, Racz, Bochenek and Sriram (2000) describe a web-based depository system for representation, sharing, and reuse of corporate design data (emphasizing the differences between databases and data repositories). Gu and Xie (1998) discuss the implementation of the dynamic engineering component database, focusing on the data organization and access. Van Leeuwen (1999) describes notations of feature types when analyzing framework for feature-based architectural modeling.

In many cases current works focus on organizing data. Arms, Blanchi and Overly (1997) recognize (1) digital materials, (2) key metadata, contained in object's definition to manage it, and (3) structural metadata that describes the types, versions, relationships and other characteristics of digital materials. There are also researchers who suggest multi-leveled architectural data organization using the XML syntax, but on the other side there are skeptics, such as Fisher, Burry and Woodbury (2000), who insist that XML specifications suffer from a conceptual deficit, and that XML was not primarily intended to provide containers for data storage but only to enable data transport between domains.

2.3. HANDLE SYSTEMS

Handles are used to identify resources over long periods of time and to manage materials stored in repository. Identifiers' concept can help with reducing data redundancy and with increasing flexibility of data structures.

2.4. SEARCH SYSTEMS

Search systems are essential for large hybrid data repositories. If using XML-notated data structures, it is important to implement search systems of both types: query-based search engines (query languages) for extracting data records from databases with known structure, and keyword search engines for searching unstructured data. When dealing with heterogeneous, complex architectural data, search systems must be well integrated with handle systems and indexing services in order to accessing unclear metadata.

2.5. THE ADVANTAGES AND THE LIMITATIONS OF XML USAGE

The XML usage for data notation has many advantages: XML syntax can be used to describe large hybrid data sets in relatively simple intuitive manner; self-describing data can be saved in ASCII files based on language-

independent UNICODE standard, shared between different applications and platforms, and managed efficiently (van Leeuven and Jessurun, 2001b).

The XML usage can add some value to user interface, for example the XML document can have many different presentation styles, which can be managed independently.

But on the other hand CAD data needs conversion to any of the existing XML dialects. Fisher, Burry and Woodbury (2000) notice, that XML itself is purely syntactical with no means for semantic definitions, so that data might easily be misinterpreted, and XML do not represent well design tasks, which consist of an unpredictable number of elements with an unpredictable number of attributes. These researchers write: "Interoperable standards require the opposite: experiences made in well-known problem spaces upon which a finite number of data elements and attributes can be collected and become specified as a problem-oriented communications protocol." Besides, the XML-based CAD data notations suffer from rough semantics. Semantics of XML-notated 'architectural' data are in many cases oriented towards needs of cost-working applications.

The overview of the existing notations is presented below.

3. The Existing Notations of Architectural Data

3.1. STRUCTURAL EXPRESS–BASED DEFINITIONS: STEP AND STEPML

STEP is not an architectural standard, but its popularity in CAD world and its features make him a potentially acceptable basis for further development for AEC. STEP is organized as a series of parts, published separately and defined using a formal specification language, EXPRESS. These parts are grouped as follows: description methods, integrated resources, application protocols, abstract test suites, implementation methods, and conformance testing. STEP uses application protocols (APs) to specify the data representation for different applications. Only a few of APs can be potentially applicable in AEC; these are the following: AP230 (Structure), AP232 (PDM), AP201 and AP202 (Draughting), AP225 (Spatial Arrangements), AP228 (HVAC), AP212 (Electrotechnical). It is expected that in the future several hundred of new APs may support many industrial applications (and AEC applications among them). On the present stage of development STEP can't really compete with other data notations in AEC application fields, especially in architecture. None of popular architectural applications uses STEP (except of general CAD drafters, such as MicroStation, which can export and import data to/from a few APs). But there were several attempts to construct STEP-based models of architectural

data, for example Popova (1998), and Watson and Wambugu (2000).

StepML is a library of XML DTD's (Data Type Definitions) that are based on the content models from the STEP standard. The 'ISO 10303-11 EXPRESS data modeling language PDM Schema version 1.2' (upon which the DTDs are based) consists of over 2100 code lines, and provides the STEP semantics to be used within the web. The stepML is not dedicated for architects and it has all the limitations specific for STEP notation. From the architect point of view it can be used for exchanging general CAD data, so its potential application in architecture is rather limited, unless the proper STEP Application Protocols and stepML schemas will be developed.

3.2. OBJECT IFC-BASED NOTATIONS: IFC, IFCXML AND BLIS-XML

The *IFC* classes were developed for a wide range of applications, such as: architecture, building services, structural engineering, project management, cost estimating and planning, maintenance, and space management. That is why IFC defines a great variety of class definitions. Relatively small part of it is dedicated strictly to architects: in effect IFC definitions lack consistency in defining architectural database structures. Besides, their structure is rather 'software-oriented': the IFC specifications are defined in the EXPRESS language, and secondly, the IFC 2.x structure is very 'atomized' (consists of the four layers and many classes). IFC seems to serve well commercial architectural applications, but it hasn't been implemented in many CAD programs yet. The existing implementations are: Architectural Desktop 2.0 and higher (Autodesk), ArchiCAD 6.5 and higher (Graphisoft), ALLPLAN/ALLPLOT FT v.16 (Nemetschek), Visio 2000 - Technical Edition (Microsoft), ARCHITREND 21 (Fukui Computer Inc.) and some cost estimating software.

The *ifcXML* defines some hundreds of IFC elements in XML syntax. 70 percent of elements' definitions do not describe spatial information, and 50 percent include information used rather by cost estimators, work schedulling programs and other non-architectural applications. The ifcXML syntax consists 2269 code lines, so this can be regarded as rather big and 'software-specific' notation not only for architects.

BLIS (*Building Lifecycle Interoperable Software*) is a small group of members of IAI developing BLIS-XML – an EXPRESS Schema notation based on XDR (XML data reduced), in order to provide efficient IFC import/export using XML syntax, to enable the use of IFC model data in applications that can read/write data in XML format only (for example standard web browsers). Its reduced, but effective syntax enables BLIS-XML to play an important role in present software development, and potentially enables its to be implemented in architectural scientific databases. These are not the only attempts to translate IFC into XML

language. An aecXML version of the IFC has also been generated.

3.3. XML-BASED NOTATIONS FOR AEC

The a*ecXML* is one of the most popular and the biggest XML dialect for AEC industry, which is being developed since 1999 by IAI and includes some stand-alone standards (such as LandXML). Now about 700 organizations, companies and individuals are involved in aecXML improvement. Its syntax is worked out by 7 working groups: Catalogs Working Group; Design/Specification/Scheduling/Costing Working Group; Facility Management Operations & Maintenance Working Group; Procurement Working Group; Project Management Working Group; Project News Working Group and Plant Working Group. This shows that developers of aecXML pay special attention to data interoperability between various application fields through product lifecycle; they do not focus on architecture itself nor they create architectural notations for stand-alone architectural databases. Besides, educational, experimental and scientific usages of aecXML are on the margins of developers' interests.

The *GreenBuildingXML* (*gbXML*) schema, published in summer 2000 by GeoPraxis, describes buildings' construction for the purposes of energy and resource analysis. It allows data interoperability between CAD programs and building analysis applications (such as DOE-2.2). The schema describes 261 elements, 85 simple data types and contains 4091 code lines.

On the opposite, the *DesignXML* is a relatively small and simple set of XML definitions describing geometry in 3D space (it has 76 code lines only). It is not sophistically oriented towards architecture, but it is rather geometry-oriented. DesignXML seems to be interesting due to its simplicity and potentially can be a base for more advanced architectural notations. It can also work with existing on-request XML formats such as SVG. DesignXML syntax allows for association XML data with undefined in schema or even external pieces of information due to elements called 'Link'. The Link element is used to associate elements in the common DesignXML channels with other bodies of information, including records in an external database. Interpretation of links is the responsibility of the applications implementing them.

The *BcXML* is the building-construction XML dialect developed by the European organization eConstruct (Electronic Business in the Building and Construction Industry) for supporting electronic business in AEC domain, and for integration of engineering AEC applications. The *adpML* is an Autodesk solution for developing and distributing electronic design catalogs that supports hierarchical part classification and allows self-publishing to a central searchable directory. Its potential for architectural databases cannot be underestimated.

The *RedlineXML* enables to exchange digital design revision markups relative to design documents. It has been incorporated into some existing CAD/PDM software, for example Autodesk's Volo View.

The *LandXML* schema facilitates the exchange of Land Planning, Civil Engineering and Land Survey data. LandXML has been embedded in aecXML. There are worked out the technologies for Converting LandXML coordinate geometry to GML (Geography Markup Language) in order to being used by GIS databases. Now LandXML Design Data Model consists of 121 elements and its code contains 2878 code lines.

The *i-drop* is an Autodesk XML-based technology which enables to create web content with the ability to drag and drop design content from a web page directly into design. I-drop works with the software, which have installed i-drop ActiveX controls (idrop.ocx). The i-drop ActiveX control is data-ignorant, because it's only responsible for transferring bytes and it doesn't interpret the data. Therefore i-drop can't be regarded as a stand-alone technology for data description in databases.

The *SVG* is an XML grammar for describing two-dimensional graphics. It includes elements for vector graphic shapes, raster images, animation, and text. There are successful attempts for applying SVG notation for describing GIS and GIS-relative information, including maps, site plans etc

4. Conclusions

1) The existing XML-based technologies (enabling application inter-operability and management of heterogeneous information) are generally not optimized for architectural data storage.
2) Merging XML notation and CAD software-specific data notations (like i-drop technology merging with adpML cataloguing capabilities) seems to be the best way to handle large amounts of architectural data, but it is not enough for building architectural databases for research purposes.
3) Defining standards for open architectural data sets is required to construct such databases.
4) Detailed investigations of XML potential in architectural notation are needed to work out software technologies and methods for scientific, semantic-insensitively communication and intuitive CAD data handling.
5) We can agree with the statement made by Fisher, Burry and Woodbury (2000) that "XML is easy to learn and applications are easily implemented but when it comes to mission critical large-scale projects, the investment in DBMS-handled storage and transaction appears to be the better choice."

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References

Anumba, C. J.: 1996, Functional Integration in CAD Systems, *Advances in Engineering Software,* 25, 103-109.

Arms, W.Y., Blanchi, C. and Overly, E.A.: 1997, An architecture for information in digital libraries, *D-Lib Magazine*, 2; *http://www.dlib.org/dlib/february97/cnri/02arms1.html.*

Fisher, T., Burry, M. and Woodbury, R.: 2000, Object-Oriented Modelling Using XML in Computer-Aided Architectural and Educational CAD: The Problem of Interoperability exemplified in two Case Studies, in *CAADRIA 2000: Proceedings of The Fifth Conference on Computer Aided Architectural Design Research in Asia*, Singapore, pp.145-155.

Gu J.and Xie G.: 1998, Dynamic Database Management in Computer Aided Residential District Design System, in: *CAADRIA'98: Proceedings of The Third Conference on Computer Aided Architectural Design Research in Asia,* (eds.) T. Sasada, S. Yamaguchi, M. Morozumi, A. Kaga, and R. Homma, Osaka University, Osaka, pp.243-251.

Houlding S.W.: 2001, XML - an opportunity for <meaningful> data standards in the geosciences, *Computers & Geosciences,* 27, 839–849.

Jakimowicz, A. and Szewczyk, J.: 2001, Multi User Interface Problems in Current CAD Systems, *in* M. Stellingwerff and J. Verbeke (eds.), *ACCOLADE Architecture Collaboration Design*, DUP Science, pp. 189-200.

Kahn, R. and Wilensky, R.: 1995, A framework for distributed digital object services, in *http://www.CNRI.Reston.VA.US/home/cstr/arch/k-w.html*.

Loudon, T.V.: 2000, Geoscience after IT. Adjusting the emerging information system to new Technology, in *Computers & Geosciences,* 26, A109-A121.

Popova, M.: 1998, Model of Design Parts and its Use to The Design Team, in *CAADRIA'98: Proceedings of The Third Conference on Computer Aided Architectural Design Research in Asia*, (eds.) T. Sasada, S. Yamaguchi, M. Morozumi, A. Kaga and R. Homma, Osaka, Japan, pp. 233-242

van Leeuven J.P. and Jessurun A.J.: 2001a, XML for Flexibility and Extensibility of Design Information Models, in *CAADRIA'01: Proceedings of the Sixth Conference on Computer Aided Architectural Design Research in Asia*, Sydney, pp. 491-501.

van Leeuven J.P. and Jessurun A. J.: 2001b, Added Value of XML in CAD, in *Proceedings of AVOCAAD 2001*, Brussels.

van Leeuwen, J.P.: 1999, *Modelling Architectural Design Information by Features*, PhD thesis, Eindhoven University of Technology, at *www.ds.arch.tue.nl/jos/thesis*.

Watson A. and Wambugu W.: 2000, A Product Model Based Architecture for Engineering Applications Software, at *www.cae.civil.leeds.ac.uk/information/papers/CIT2000.htm*.

Szykman, S., Racz, J., Bochenek, C. and Sriram, R.D.: 2000, A Web-based System for Design Artifact Modeling, in Design Studies, 21(2), Elsevier Science Ltd., pp.145-165.

FROM CAD TO IAD

A Working Model of the Internet-Based Engineering Consulting in Architecture

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Abstract. Information technology has become so powerful that what is conventionally called CAD might evolve into **iAD** (Internet Aided Design) in the near future (Zhou 2000). For Internet applications in the AEC industry, most of the efforts and success have been concentrated on project management and collaboration, while in the design and engineering consulting area, limited progress has been made. During the period of Internet development, the nature of the fragmentation of the AEC industry has not been changed**.** Based on previous research of surveys of development of Internet applications in the AEC industry (Zhou 2001), and the study of information technology both available today and in the near future, we propose a general abstracted model of an Internet-based consulting system by integrating a variety of disciplines and functions of design and construction processes. This model will cover a range of design phases, such as, information gathering, automatic remote consultation, specific problem solving, and collaboration. Finally, in future follow up research, we will apply the proposed model to steel construction in architectural design, and develop a prototype simulation by selecting one type of structural system.

1. Concepts and Philosophy

Our initial research defined the scope, process and activities of engineering consulting in architecture. On analysing the deficiency of the conventional processes of engineering consulting in architecture, as compared to

conventional engineering consulting, we attempted to determine the potential significance of the Internet-based consulting system, and discuss three types of Internet consulting systems in terms of scale and complexity of services.

1.1 DEFINING THE ENGINEERING CONSULTING IN ARCHITECTURE

In order to better understand the entire process of engineering consulting in architecture, we need to define a series of concepts that describe it, such as, the scope, content, activities, relationship among the processes, partners and contents. Figure 1 shows the overall organization of engineering consulting in architecture.

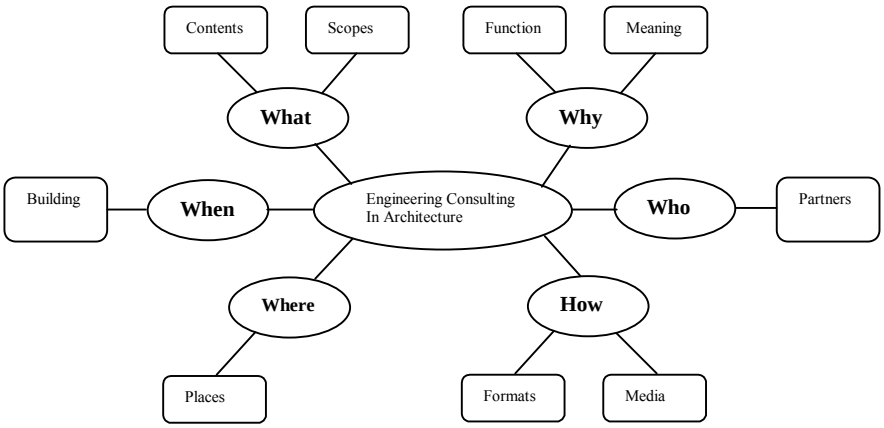


Figure 1. *Definition of engineering consulting in architecture*

A more detailed configuration of this definition is given in Table 1. In this table, we include all major aspects of engineering consulting. For participants or partners, two types are identified as primary participants and secondary participants by the roles they play in the consulting activities. For building process and scope of consulting, all are based on North American modes in general building project types, which may be partially true for the rest of the world. Social factors are very important in introducing any new technology into the AEC industry because its sophisticated social and cultural impact, such as, people's behavior, psychological influence, personal relationship, national and religious influence. "Any activity dependent for its success on a revolutionary change in people's actual attitudes towards their works was unlikely to succeed." (Laiserin 2002). There are at least two concepts that can be applied to the function and meaning of engineering consulting. One is to integrate the responsibility of

engineering issues into the entire architecture process. This is addressed because of the apparent separation of the modern building industry into different disciplines. Second, convert architectural ideas into feasible engineering solutions.

TABLE 1. Definition of engineering consulting in architecture

Participants or Partners	Primary Participants	Architects Engineers: mechanical, structural, environmental , construction	
	Secondary Participants	Owners, contractors, regulators, vendors	
Design & Building Process	Planning Conceptual design Schematic design Analysis Construction documents Shop drawing documents Construction coordination Post occupancy evaluation Building management	Scope of Consulting	Structural engineering Mechanical engineering: HVAC, Plumbing, electricity Information engineering: intelligent building, computer Networking, Communication, … Environmental engineering: acoustics, noise control, air & light quality Construction engineering Building material research Urban development
Contents of Consulting	Engineering analysis Building codes Material selection Specifications Construction advise Vendor references	**Formats of Consulting**	Numeric information Tabular information Calculations Text documents Physical models Drawings Audio and video
Media of Consulting	Personal meeting and discussion Calculation and analysis Electronic media for communication: email, online meeting	**Places of Consulting**	Architect offices Engineers offices Construction sites Cyber space

In this proposed model of an Internet-based engineering consulting system, we should consider the scattered and sophisticated nature of the AEC industry, and assemble all of the attributes as shown in Table 1, into a logical and programmable system to integrate all major disciplines.

Next, we examined the relationship among process, participants and activities in the entire design and construction period. Figure 2 shows those basic relationships horizontally and vertically. The workflow or process is the fundamental sequence linking all participants together dealing with the activities occurring in different phases. Several points in this relationship should be considered as key factors while creating an Internet-based consulting model. First, through the entire process, architects and engineers should play a leading role in the design and construction activities. They should be the primary targeted users in the new Internet model. They still play an important role and should not be neglected as secondary users. Second, in each process, there are multi-cross discipline activities occurring simultaneously. We should revolutionize the traditional work model, which

now isolates these activities based on different disciplines, such as, different computer software, different sets of documents, and different working places.

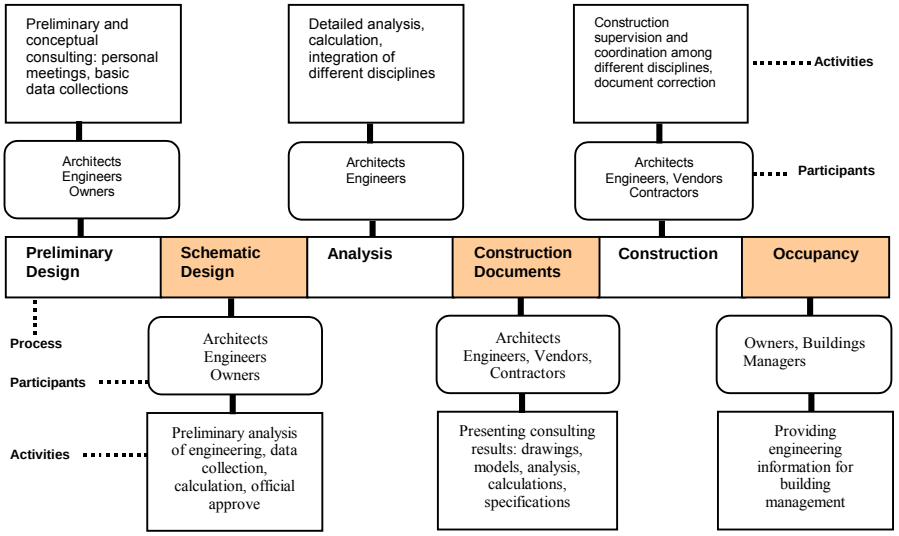


Figure 2. Relationship of process, participants and activities

1.2 COMPARISON OF CONVENTIONAL WORKING MODEL WITH THE INTERNET-BASED WORKING MODEL OF ENGINEERING CONSULTING

Listed here is a series of comparable attributes in two different working models in order to determine the potential of Internet applications in the AEC industry. For efficiency of these two models, we can see that due to the nature of the AEC industry, fragmentation and scattered components of design and construction may result in low efficiency. At the same time, in the engineering consulting process, large portion of consulting services are ordinary routine activities, but still require personal contact and case-by-case solutions, and very low automation. However, an Internet-based working model can largely improve the efficiency by integrating the scattered issues and by remote automation in solving the routine job of personal meeting and contact, and by an integrated digital work flow from design to manufacturing to construction. In the modern movement of architecture, one major direction is towards custom mass production, which follows industrialization and standardization. In this post-industrial period, people are seeking personalized life styles and customized architecture, which usually results in high cost and longer construction time. By using Internet technology, we can

dramatically reduce the cost and save time by a highly integrated digital working format. We already see this development in the manufacturing industry. “Dell computer has demonstrated that assemble-to-order is more efficient than mass production, and even more build-to-order will be more so.” (Ping Fu 2002).

1.3 CATEGORIES OF INTERNET CONSULTING SYSTEMS

There can be three categories of Internet-based consulting in terms of scope and format. One is comprehensive services, including design, collaboration, management, so called “one stop shopping” like Wal-Mart, the biggest comprehensive retailer in the world. Second is categorized services, to include one or two aspects required in the AEC industry, such as project management, one discipline consultation, similar to Toys”R”Us, a major toy products store. The third is task specific, such as online printing, online library, like Tiffany and Co., a jewelry retailer.

2. Technology and Tools in the Near Future

Our proposed model is based on both current and near future information technology, part of which will be needed and applicable to the AEC industry. Three types of tools are essential in creating this working model.

2.1 UNIVERSAL INTERNET PLATFORM

An open and universal platform allows applications to communicate and share data over the Internet, regardless of operating system, device, or programming language, which ultimately will result in a seamless integration of internal and external web applications, such as what Microsoft .NET technology intends to do. In our proposed model, we need such an open Internet platform in which, various kinds of web sites, software, information and services can be linked and integrated into entity for seamless workflow.

2.2 Fully ASP

ASP (Application Services Provider) is defined as “the provider of a web based environment where applications and data are centrally stored” (Emmerik 2001). It is estimated that in next three to five years, ASPs will be the standard platform for delivery of all business applications (Unger 2001). In the proposed model, all applications are designed as ASP format, which can greatly reduce the cycle time and cost of updating software. Also, it will meet one of the requirements for the AEC industry to revolutionize the entire process by standard digital workflow from design to manufacturing to construction.

2.3 CLIENT SERVER INTERFACE MODEL

The interfaces for the model will consider to fully 4D objects, virtual reality, hand and voice input for direct and convenient interaction, following the nature and habits of what the AEC professionals used to in conventional ways. The CAD fields already evolve towards the direction of object-oriented and user-friendly working environment.

3. Proposed Working Model

3.1 GENERAL TARGETS AND UNIVERSAL PLATFORM

The Internet changes the way of work in all major phases in the AEC industry. In this proposed model, we assume that most of the activities and contact will happen in cyberspace. Figure 3 shows these relationships. Architects will play the principal rule in organizing the entire project process. To all of the participants, architects no longer have to have face-to-face contact and consult with them except with clients or owners because social and cultural affairs still need human contact between clients and representative designers, the architects. All partners can work with each other through the Internet consulting central server.

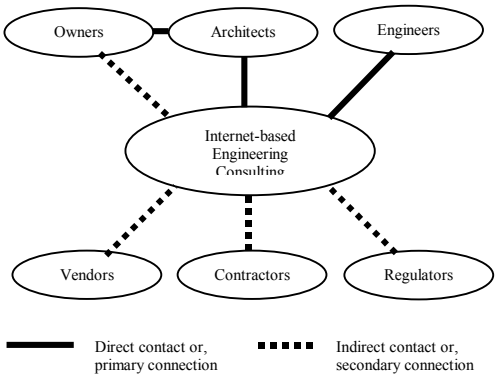


Figure 3. *General model and its targets*

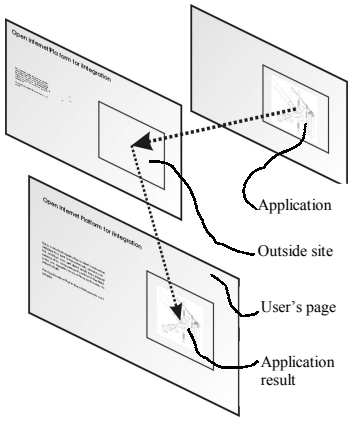


Figure 4. *Universal platform*

Figure 4. shows the universal platform, which connects the home server with outside resources, such as, individual project information and related applications. The results of applications either from in-house or external resources should be able to directly feed back to user's project page. For this consulting model, as design applications are the main function rather than management, or collaboration, we naturally take designers as the primary users. At the same time, as the functionality goes into the other engineering

phases, and as other partners become involved in the design, developers, contractors and vendors can also use this service.

3.2 MODEL ORGANIZATION

Some key concepts and methods have evolved in organizing the model, such as, integration of disciplines, self-cycling of process, combination of remote automatic problem solving and on-line personal interviewing, and optimisation of business models.

3.2.1 Discipline Integration and Process self-cycling

Unlike the separated conventional engineering consulting based on different disciplines, this is a self-cycling process for engineering consulting, integrating all applications from architecture, structure, mechanic system and environmental systems as displayed in Figure 5.

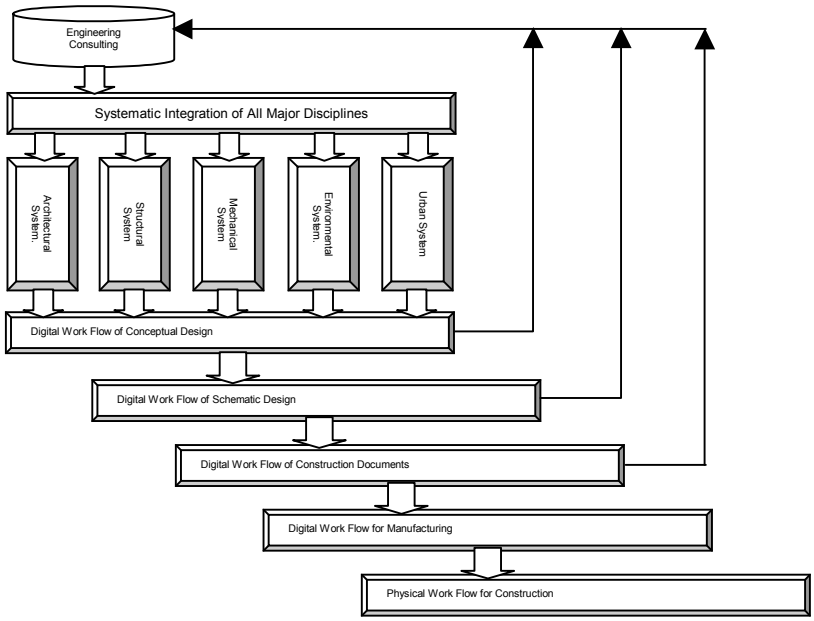


Figure 5. *Integration and cycling process*

Users login to the central server, enter their initial project parameters on an designer friendly and familiar interface, the system generates applications in each design phase, and users revise the results and progress to next design phase until the final and satisfied results reached. The result is an integrated product, containing conventional construction documents and digital work flow to manufacturing, then as physical work flow to construction.

3.2.2 Combination of Remote Automation and Customisation

The majority of engineering consulting is routine and can take place by using programmed expertise. In this model, all of these implementations are ASP based, in which, remote, automatic and instant solution can take place. For some special customized engineering issues, virtual reality tools could be used on personal expertise basis. A project-oriented approach is adopted in this model, in which, all major applications are related directly to design and construction processes. This proposed model includes information gathering, design and consulting applications, procurement, project management, and on-line collaboration.

3.2.3 Consideration on Marketing and Business Models

Profitability is a key issue for all web vendors to survive. However the fact is that most of the contemporary vendors are not profitable, as we have seen the Internet bubble burst in recent years. The fundamental reason is the lack of mature integrating service for the AEC industry, and still low use of Internet technology. As this model is intended to be an integration of the entire building process with engineering consulting and design services as the core, there are number of methods to generate revenues, such as, subscription based application services, project based services, commission based third party services, and finally technology licensing.

References

Emmerik, M.V.: 2001, An end-to-end Solution for Improving the Efficiency of the Building Design And Management Process, *www.bricsnet.com*

Laiseri, J.: 2001, Online, Out-of-Line, End-of-the-Line, *in Cadence 12/20001* *www.cadenceweb.com/2001/2011/collaboration1201.html*

Ping, F.: 2001, From Part to Art, *in Cadence 12/2001* *www.cadenceweb.com/features/interviews/pingfu.html*

Unger, S.: 2001, Why ASPs Will Dominate AEC *www.constructware.com/ecommunity/industryInsider*

Zhou, Q. and Krawczyk, R. J. and Schipporeit, G.: 2000, From CAD to iAD, *Ph. D Proposal* (Unpublished), College of Architecture, Illinois Institute of Technology, USA.

Zhou, Q. and Krawczyk, R. J.: 2001, From CAD to iAD, A Survey of Internet Application in the AEC Industry, *in ACADIA 2001 Conference Proceedings,* 392-397.



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THE IMPACT OF INTERNET ENABLED COMPUTER AIDED DESIGN (ICAD) IN CONSTRUCTION INDUSTRY

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Abstract. The advent of the Internet has opened up and given, particularly, the developing countries and the world in general, a transformation into collective intelligence (Levy, 1998) societies linked to digital communication (Rafi, 2001). Apart from large corporations, the rapid evolution of border-less communication has also synergise between the art and science expertise to form low-cost internet-based networks that have become multi-million dollar companies within a short period of time (e.g. Linux) (Rafi, 2001). In the context of architectural designs and construction industries, the birth of Internet-based CAD (iCAD) solutions has offered a new dimension to architectural practice. The function of CAD has expanded as a tool to communicate and collaborate as well as to better control all phases of the architectural practices. This paper will review the current available iCAD tools and explore the possible utilisation of iCAD in architectural practices. The opportunities for modifying current professional practice standards to best use iCAD will be rationalised as well as the elements in ensuring the effectiveness of iCAD implementation. The final component of the paper will be an evaluation framework to measure the value of iCAD in an architectural practice. The framework will become an early platform for an architectural practice to decide and plan their future in utilising and applying iCAD in the most efficient way.

1. Introduction to iCAD

Computer Aided Design (CAD) tools exist to design construction plans with a dimensional accuracy and clarity. Just as normal CAD, iCAD tools have the entire CAD features with a few value-added features (Day, 2001). The difference is that, unlike normal CAD, iCAD is supported with communications and collaboration tools (which is actually sharing of

knowledge and information) that were previously enabled by additional system called Computer Information Systems (Cornick, 1996). Unfortunately since it was a separated system, the architectural profession has largely ignored it despite professional realisation on clear advantages of the system (Cornick, 1996). The combination of CAD and CIS is empowered with the emergence of new technologies such as the Internet and Networking. The myriad data and information involved will be simultaneously recorded, up-dated and accessible by all the team members all the time, reducing much of the project cost and time cycles (Cohen, 2000). In this sense Internet enabled features are becoming a differentiate factor in architectural practice.

1.1. INTERNET ENABLED FEATURES

Green (2001), in analysing AutoCAD 2000i has divided Internet enabled features according to their centric functions: user-centric functions and collaborative-centric functions.

TABLE 1. Summary of Internet features in AutoCAD 2000i.

Function	Features	Featuring
User Centric	AutoCAD Today	Information access via a live browser connection
	Hyperlink dialog box	Insert hyperlinks into objects
	xref. support	Support for external references and drawing directories
	e-Transmit	Internet/email transmittal of work packages
	i-drop	Importing of drawing content from vendor sites
	Meet Now	Internet based training support
Collaborative/ Customer Centric	Publish to web	Electronic publishing/sharing of drawing files
	e-Plot	Electronic mark-up and draft printing of drawing modification
	Meet Now	Internet-facilitated meetings and conferences

As described in table 1, most of the features identified by Green are the features to enhance the communication and collaboration process via Internet; the closest competitor, ArchiCAD is developing Geometric Description Language (GDL) and Virtual Building as the platform for communication and collaboration, as reviewed by Day (2001) and summarised in Table 2 (the framework of table 1 is used for comparison purpose):

TABLE 2. *Summary of Internet features in ArchiCAD 7.0.*

Function	Features	Featuring
User Centric	GDL Central	GDL objects catalogues via a live browser connection
	Hyperlink dialog box	Insert hyperlinks into GDL objects and drawing objects
	Project Publisher	Internet/email transmittal of work packages
	GDL drag and drop	Importing of GDL objects from GDL Central or vendor sites
Collaborative/ Customer Centric	Object Publisher and Project Viewer	Electronic publishing/sharing of drawing files
	Project Publisher	Draft printing of drawing modification
	Project Mark-up	Electronic mark-up and redlining

1.2. INTERNET COLLABORATION TECHNOLOGY

Besides the new iCAD features, there are a few Internet collaboration technologies that have been developed and are available on-line, with the intentions to surface the iCAD benefits and match them with the real-world architectural problems. The technologies are not part of the iCAD, but are part of the infrastructure that supports collaboration via Internet; Exchange (Virtual Marketplace), Extranets (Project Collaboration Network), Internet Portals, Vertical Portals (Vortals), [5]Video Conferencing and [6]Application Service Provider. Application Service Provider (ASP) is the most comprehensive technology that supports collaboration and communication via Internet (Laiserin, 2001). The integrated project database capability offered by ASP is the most promising solution for the architectural practice, as they face the changes in their roles (which will be discussed in change of architect roles) since it virtually integrates the Computer Information System (CIS) into iCAD.

2. Applications and Impacts of iCAD

This section will describe the application of iCAD in architectural practice (with focus to the less explored area), and explain the changes and impacts of the iCAD application. Five layers have been identified in the analysis (i.e. in reference to architectural practice phases) namely Program/Brief, Design Development, Working Drawing, Contract Document, and Construction.

2.1. PROGRAM/ BRIEF PHASE

The current usage of CAD in the brief phase is minimal due to the uncertainty of the project being continued into the next phase. There is opportunity to use iCAD at this phase especially in identifying client/market's requirements and the information in justifying a design intention/rationales. Growing numbers of clients may have their own computer-based system to support their businesses. They would appear to have adequately described their business operations and activities in order for architects to directly translate them into a briefing for building/spaces. Geographic Information System (GIS) can be manipulated in providing the spatial and descriptive information on the site and it's surroundings. The public interest and government regulation will be implemented at the earliest stage of a design/construction process.

2.2. DESIGN DEVELOPMENT PHASE

The use of information in this phase is unquestionable. The ubiquitous information and data in the Internet might be the most well-known Internet benefit. The sharing of information and knowledge exchange will speed up the design cycle (e.g. information on new material and construction technique) The advent of information/knowledge management will help architect to concentrate in design with less resistance. The design feedback/approval from the government, statutory bodies, client and even the community will be much faster and more accurate. The process of conceptualisation, visualisation and expression will be an interactive process. In a boarder sense, architects will not just achieve a better design with the use of iCAD, but will also enable them to contribute to the expanding collection of data, information and knowledge.

2.3. WORKING DRAWING PHASE

The use of iCAD in the working drawing phase is able to reduce the time and cost of multiple drawing production, printing and delivery. The new features, such as inserting hyperlinks are promising improvement in the quality of information in terms of accuracy and authoritativeness. For the other consultants, their decision-making and calculation will be more accurate since most of the information required by them is linked to the object in the drawing (even for the case of new material and new construction method). This is supported with the new Internet technology which makes collaboration is much easier.

2.4. CONTRACT DOCUMENT PHASE

The use of iCAD will simplify the bidding and procurement paper trail (i.e. tender can be offered, managed and received via Internet). The project management planning such as material, human resource and machine availability can be justified earlier. There is opportunity for the supplier and manufacturer to project the market demand beforehand. These facilities will help architects and clients to reduce the variation order and possibilities of project delay.

2.5. CONSTRUCTION PHASE

The most promising Internet technology at this phase might be the capabilities to monitor project from distance. A few cameras will be located at the construction site. Any changes that are varied from the tender document can be recorded and all the parties involve can be alerted simultaneously, the instruction from the architect and other consultant can be validated instantly. The integration of iCAD with project management software (currently available in web-based) will help a lot in improving the construction site quality of work.

3. New Roles for Architectural Practice

According to Architect Code of Professional Conduct, there are a few special skills of a professional architect, which are capabilities to create, design, plan, manage and supervise construction project (PAM, 1996). The use of iCAD is calling for a new communication and collaboration skills, which were not mentioned since it is considered as the common skills in any business area. This section will try to describe a few views on the new roles of architectural practice.

3.1. CHANGE OF ARCHITECT ROLES

In international scenarios, American Institute of Architect (AIA) in their Governance Policies, set out a vision in which practitioners will increasingly be called upon to manage complex set of interwoven professional relationship (Laiserin, 2001). They also envisage architect to assume a central role of facilitator and integrator of the knowledge and disciplines needed. Royal Institute of British Architect (RIBA) in the Guidance Notes for School of Architecture on Examinations in Professional Practice (1998) has emphasised the importance of communication and collaboration in architectural practice as being outlined in the syllabus. From the knowledge

economy (k-economy) point of view, architects are becoming knowledge managers where knowledge management is considered as new skill, which has to be mastered by them. In order to play this new role, architect has to be able to facilitate collaborative working members of a construction project team and allows consistent integration of all project data as well as greater data integrity. The adoption of iCAD might be utilised to equip architectural practice in facing the new challenges as a knowledge manager since most of the new iCAD features deal with CIS.

3.2. NEED FOR CHANGES IN ARCHITECTURAL PRACTICE SYSTEM

More than ever, architectural practices face the challenge of improving business processes to produce the results internal and external consumers want. The next stumbling block towards maximum manipulation of iCAD is might be not the technology, but rather the willingness of architectural practice to review the procedures by which they do work and willingness to revise existing procedures as well as allocation for Information Technology development (Cohen, 2000). There are three identified elements that need extra attention from architectural practice in order to ensure the system works properly namely Participant, Information and Technology. It should be noted that the concentration should be on how work is being done using iCAD rather than the technology itself, and the balance between the respective elements. The whole system of architectural practice business process and the construction industry environment might need to be reviewed to achieve full potential of iCAD, including the preparation of an evaluation framework to assist them in preparing for the changes.

4. Evaluation Framework

The evaluation framework is primarily developed to find balance according to the need of each practice. The need is determined by the strategic mission of a practice. The gap between the strategic mission and the actual practice's competencies can be identified as a strategic gap that needs to be faced by a practice. There should be a link between the architectural practice elements with the practice structure as well as with the environment. Strategic Structure is representing the new form of architectural practice where all the alignments will meet and the strategic gap will be filled (figure 1).

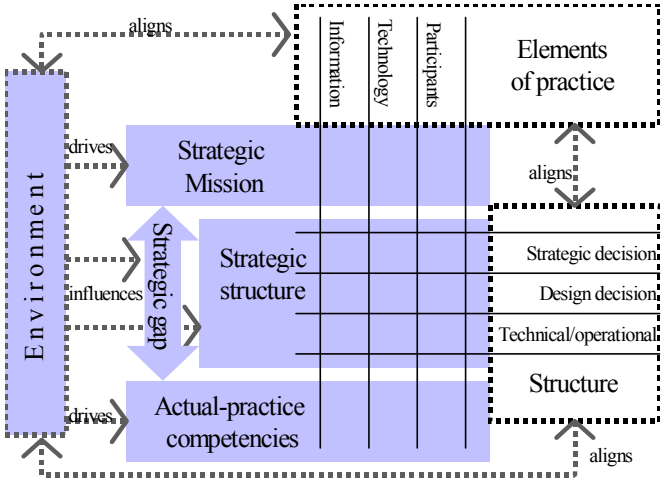


Figure 1. Defining and aligning the strategic mission with the actual-practice's elements.

The process will provide feedback and new synthesis (due to the dynamic of knowledge and technology). The use of iCAD will help architectural practice to go through the process since iCAD is capable to receive, record, store and help architects to manage the information. Architectural practice as well as construction industry should manipulate the information in order to remain innovative in facing the ever-changing business environment.

5. Conclusion

The introduction of iCAD has a great impact on the construction industry. Architectural practices have to revise their roles as a knowledge manager primarily to gain new knowledge and skills. The utilisation of iCAD is part of the tools and powerful for the architects in realising their new role since iCAD as virtually embedded in CIS. There are also calls for architects to continuously revise their strategic mission, skills, technology and knowledge to remain competitive in the industry. The evaluation framework will help architectural practice to set-up a learning-organisation and iCAD once again will become an essential tool in enabling architectural practice to face the wave of changes.

References

Levy, P.: 1998, *Becoming Virtual: Reality in the Digital Age,* Plenum Publishing.
Malone, T. W. and Laubacher, R. J.: 1999, Creating Value in the Network Economy, Tapscott, D. (ed.), *The Dawn of the E-Lance Economy*, Harvard Business Press, pp. 55-67.

Rafi, A.: 2001, *Design Creativity in Emerging Technologies*. Ars Electronica 2001: Takeover: Who's Doing the Art of Tomorrow. Von, H (eds). SpringerWein, New York.

Day M. (2001, May 18). *Do you need AutoCAD 2000i?* [On line] available :http:/www.cadserver.co.uk/common/viewer/archieve/2000/May/18/feature1.pthm

Cornick T. (1996). *Computer Integrated Building Design* London: E&FN Spon. pp. 2-10

Cohen J. (2000). *Communication and Design with the Internet* (chapter 1) [On line] available: http://www.jcarchitects.com/communication.html

Day M. (2001) *Graphisoft delivers Web tool kit for ArchiCAD*, [On line] available http//:www.cadserver.co.uk/common/viewer/archive/2000/May/25/news2.pthm retrieved on 19 July 2001

Laiserin J. (2001). Technology for design collaboration [On-line] available http://www.archrecord.com/digital/da_artic/da03_01.asp

Board of Architects Malaysia. (1986). *Code of Professional Conducts.* Kuala Lumpur: Lembaga Akitek Malaysia

A SHAPE COMPACTNESS MEASUREMENT INDEXING WITH FUZZY MULTICRITERIA DECISION MAKING APPROACH

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Abstract. Compactness of a district or zone is determined by considering its appearance and the area of dispersal of the district (Altman, 1998) and it is used as a characteristic to describe shape (Shiode, 1998; Knight, 1997). However, existing compactness measurement used to assess district plans in redistricting applications are vague and imprecision although there are more than thirty over Euclidean or non-Euclidean measurement methods. Therefore, this paper presents an integrated shape compactness measurement indexing with a fuzzy multicriteria decision making approach (FMCDM) to enhance the measurement of shape compactness. An experiment is conducted in order to verify the practically of the proposed model to improve existing compactness measurement method.

1. Introduction

Compactness includes a mathematical analysis of the shape and regularity of the spatial shape. Laurini & Thompson (1992) mentioned that shape refers to the structure of the mode of arrangement related to function or the appropriateness and effectiveness of purpose. It is important in control of the district shape or district boundary complexity because irregular geographical boundaries may cause oddness in district shape in various applications such

as election zone rearrangement, sales territory management for business and forest resources planning applications.

Compactness measurement for district compactness and continuity assessment gives an index for assessment of compact district or zone (Bong, 2001b). However, existing compactness measurement used to assess district plans in redistricting applications are vague and imprecision although there are more than thirty over Euclidean or non-Euclidean measurement methods (Altman 1998; Bong 2001a). Frequently, decision making in this district assessment involves uncertainty of the data acquired and the variety of evaluation tools. In addition, numerical measurements in compactness measurements give uncertain and vague value for accurate assessment of district compactness and continuity. Altman (1998) uses an axiomatic analysis to join formal measures of compactness to analyze the consistency of the Euclidean compactness criteria and he proved that most compactness indices satisfy one shape axiom, but violate others. Furthermore, Dominique & Michel (1999) showed different methods for getting fractal dimension may change due to different condition. Thus, existing compactness measurement methods perform differently to different circumstances and single methods alone is not effective enough because each of the method may suffer from its limitation.

Therefore, section 2 presents an integrated shape compactness measurement indexing with a fuzzy multicriteria decision making approach (FMCDM) to enhance the measurement of shape compactness. The generation of the integrated compactness index is based on the synthesis of the concepts of fuzzy set theory, Analytical Hierarchical Process (AHP), α-cuts concept, index of optimism of decision maker to estimate the degrees of satisfaction of the judgments on a district plan and their attitudes toward risk. We use the fuzzy set theory and Analytical Hierarchy Process to formalize the gray area because it provides fuzzy numbers that are easy to use in expressing qualitative assessments of the Decision-Makers, DM (Deng 1999, Chen 1996, Mon 1995, Yeh 1997). An experiment is conducted in order to verify the proposed model in section 3. Results and analysis from the experiment showed the effectiveness of the integrated indexing with the ability to cope with fuzziness and multiple aspects of compactness measurement. Lastly, the paper outlined potential improvement and recommendations for future use.

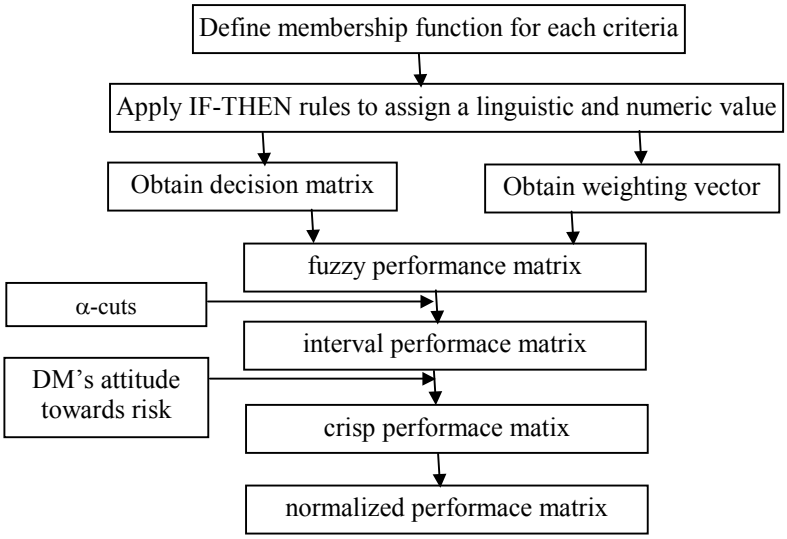


Figure 1: Architect Design for the constructing the proposed integrated compactness measurement indexing

2. Design For Integrated Compactness Measurement Indexing With Fuzzy Multicriteria Decision Making

The design for constructing the integrated compactness measurement for this paper is summarized in Figure 1. Firstly, we apply fuzzy set theory in constructing rulesets for each criteria of the integrated compactness measurement before we integrate multiple criteria by using Fuzzy Analytical Hierarchy Process. The ruleset plays an important role to determine the optimality of district compactness. We define the rules by linguistic terms and their membership function. Linguistics terms are defined for each of the selected criteria and their weighing vector (Herrera and Verdegay, 1995). In addition, we use the definition of the interval of confidence at level α (α-cuts). This helps characterize the triangular fuzzy number as

$$\forall\alpha \in [0,1],$$
$$\overline{\mathrm{A}}_n = [a_1^n, a_3^n] = [(a_2 - a_1)\alpha + a_1, -(a_3 - a_2)\alpha + a_3] \quad (1)$$

The method used will give an effectiveness level (x) to each of the selected criteria (C). The effectiveness levels belong to a set of linguistic terms that contains various degrees of preference required by the DM. This study use linguistic terms x (effectiveness, x) = {Very Poor (VP), Poor (P), Fair (F), Good (G), Very Good (G)}, defined in Figure 2. A membership

function, which assigns to each linguistic term with a grade of membership, is associated with the fuzzy set in [0, 1]. When the grade of membership for a linguistic term is one, it means that the linguistic term is absolutely in that set and verse vice. Borderline cases are assigned values between zero and one.

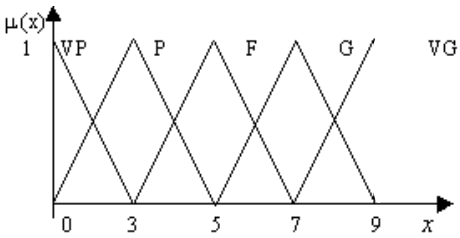


Figure 2: Membership functions, μ(x) and the linguistics terms for effectiveness (x) of each criterion (C)(Bong, 2001b)

Considering the different importance of criteria, different weights are determined for each criterion. By pairwise comparison of the relative importance of criteria, the pairwise comparison matrix is established based on pairs of criteria *Ci*, and *Cj*. The comparison scale ranges from 1 to 9. To facilitate the making of pairwise comparison, triangular fuzzy numbers defined in Table 1 are used. A triangular fuzzy number $\bar{x}$ expresses the meaning of 'about *x*', where $1 \leq x \leq 9$, with its membership function. Fuzzy number $\bar{x}$ used by Deng (1999) is revised here to better reflect the decision situation involved.

Table 1: Linguistic terms used by the decision matrix (Deng, 1999)

Linguistic term	Very Poor (VP)	Poor (P)	Fair (F)	Good (G)	Very Good (VG)
Fuzzy number	$\bar{1}$	$\bar{x}$			$\bar{9}$
Membership function	(1, 1, 3)	$(x-2, x, x+2) for x = 3,5,7$			(7, 9, 9)

By using the fuzzy numbers defined in Table 1, a fuzzy reciprocal judgment matrix for the decision matrix for m criteria and n alternatives is given as

$$X = \begin{bmatrix} x_{11} & x_{12} & \ldots & x_{1m} \\ x_{12} & x_{22} & \ldots & x_{2m} \\ \ldots & \ldots & \ldots & \ldots \\ x_{n1} & x_{n2} & \ldots & x_{nm} \end{bmatrix} \quad (2) \qquad W = (w_1, w_2, \ldots, w_m) \quad (3) \qquad Z = \begin{bmatrix} w_1 x_{11} + w_2 x_{12} + \ldots + w_n x_{1m} \\ w_1 x_{12} + w_2 x_{22} + \ldots + w_n x_{2m} \\ \ldots \quad \ldots \quad \ldots \quad \ldots \\ w_1 x_{n1} + w_2 x_{n2} + \ldots + w_n x_{nm} \end{bmatrix} \quad (4)$$

where x_{ij} represent the linguistic assessments of the performance rating of alternative $A_i(i=1,2,...n)$ with respect to criterion $C_j(j=1,2,...m)$. The weighting vectors for the evaluation criteria is given directly by the DM or obtained by using pairwise comparison of the AHP as defined in Table 1. Then, the model obtains a fuzzy performance matrix (5) representing the overall performance of all alternatives, with respect to each criterion by multiplying the weighting vector with the decision matrix.

By using a α-cut (1) on the performance matrix (4), an interval performance matrix can be derived as in (5), where $0 \le \alpha \le 1$. The value of α represents the DM's degree of confidence in his/her fuzzy assessments regarding alternative ratings and criteria weights. A larger α value indicates a more confident DM. Incorporated with the DM's attitude towards risk using an optimism index α, an overall crisp performance matrix is calculated in (6) by $z_{i\alpha}^{\lambda'} = \lambda z_{ir}^{\alpha} + (1-\lambda) z_{il}^{\alpha}, \lambda \in [0,1]$.

$$Z = \begin{bmatrix} [z_{1l}^{\alpha}, z_{1r}^{\alpha}] \\ [z_{2l}^{\alpha}, z_{2r}^{\alpha}] \\ \cdots \\ [z_{nl}^{\alpha}, z_{nr}^{\alpha}] \end{bmatrix} \quad (5) \qquad Z_{\alpha}^{\lambda'} = \begin{bmatrix} z_{1\alpha}^{\lambda'} \\ z_{2\alpha}^{\lambda'} \\ \cdots \\ z_{n\alpha}^{\lambda'} \end{bmatrix} \quad (6) \qquad z_{i\alpha}^{\lambda} = \frac{z_{i\alpha}^{\lambda'}}{\sqrt{\sum_{i=1}^{n} (z_{i\alpha}^{\lambda'})^2}} \quad (7)$$

λ= 1, λ=0.5, and λ= 0 are used to indicate that the DM involved has an optimistic, moderate, or pessimistic view respectively. An optimistic DM is apt to prefer higher values of his/her fuzzy assessments, while a pessimistic DM tends to favor lower values. After the facilitation of the vector matching process, a normalization process in regard to each criterion is applied to (7), resulting in a normalized performance matrix expressed. The values of N_{α}^{λ} indicate the degree of preference with respect to the alternatives for fixed α and λ, respectively where $\alpha \in [0,1], \lambda \in [0,1]$. Indeed, this value is the Integrated Compactness Indexing (ICI), which considers all the compactness measurements or evaluation criteria earlier. The larger the value, the more compact the shape and the less complex is its boundary, thus the more preference the alternative.

3. Experiment

An experiment is conducted in order to verify the practically of the proposed model to improve existing compactness measurement method. Specifically, we determine two different compactness measurement methods to consider the compactness criteria and they act as two different separate criteria. They include the non-Euclidean measurement based on fractal dimension (FD)

and the Euclidean measurement based on area-perimeter ratio (EM). The higher the fractal dimension, the more complex it is for the district boundary. Subsequently, the district compactness is determined by the value on the fractal dimension. Thus, we choose to use box counting dimension to calculate the fractal dimension. First, we need to cover a zone by 'r'-size boxes and determining how many boxes of a particular size 'r' intersect the image (Knight, 1997). Thus, the number of boxes of size 'r' is needed to cover the zone is given by:

$$N(r) = \frac{i}{r^D} \tag{8}$$

$$\log(\text{box count}) = a + b \log(\text{box size}) \tag{9}$$

Then, the size 'r' is changed to progressively smaller sizes and the corresponding numbers of non-empty boxes are counted N(r). The logarithm of N(r) versus the logarithm of 1/r gives a line whose gradient corresponds to the box dimension. The intercept is represented by a, and b is the slope. The fractal dimension D is represented by the absolute value of the slope b. Meanwhile, the EM is based on equation below:

$$compactnes\ s = \frac{Perimeter^{\,2}}{Area} \tag{10}$$

The third criterion selected is the size of the district or the zone. Three criteria are considered with respective weight value to produce integrated compactness measurement indexing, ICI.

Figure 3 shows the comparison result for the each compactness measurement index for the two of the selected criteria, EM and FD and the proposed indexing, ICI normalized from circle (polygon 2). It is clear that ICI could perform well not only to react the area and perimeter control but also for the boundary complexity. On the other hand, FD could not assess the polygon compactness very well because it gave a blur and imprecise index.

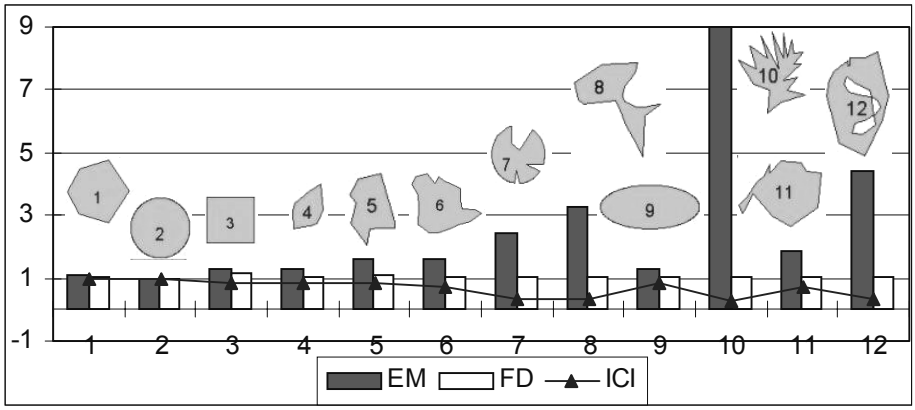


Figure 3: Comparison on different compactness measurement index

4. Conclusion

The paper has been completed successfully despite all the constraints being posed to. The most profound accomplishment among all is the success in obtaining Integrated Compactness Indexing by incorporation fuzzy multicriteria decision making for compactness measurement index. Though the information sources are limited, it is enough to prove the applicability of the developed redistricting algorithm to incorporate shape compactness information into redistricting technique. The algorithm is simple and yet efficient as compared to other more complicated methods. The result is satisfactory and comparatively better than other traditional approaches as well. The success of definition, modeling, and incorporation of the tertiary information also highlighted the applicability of Fuzzy Multiple Criteria Decision Making approach in compactness assessment.

5. Recommendation

The research can be extended especially in analyzing the relationships (correlation) and interdependence between various shape criteria. The detail analysis on their relationships may help their consideration in the model to enhance the result of the redistricting technique. Presently, researches are mutually exclusive and no detail study has been done to analyze the their relationships.

Acknowledgements

We would like to thank *Pelan Tindakan Pembangunan Teknologi Perindustrian* (PTPTP), University Malaysia Sarawak for the financial support for this research.

References

Altman, Micah (1998). Redistricting Principles and Democratic Representation. Ph.D. Thesis. California Institute of Technology. Pasadena, California.

Bong C. W. (2001a). "Fuzzy Multiple Criteria Decision Making Method In Integrating Compactness Measurement For Shape-Based Redistricting". A research thesis for Master Degree study of Faculty of Information Technology, Universiti Malaysia Sarawak.

Bong C. W., Wang Y. C. (2001b). "Compactness Measurement Using Fuzzy Multicriteria Decision Making For Redistricting". International Conference on Electrical and Electronic Technology, TENCON 2001.

Chen Shyi-Ming (1996). A new Method for Evaluating Weapon System Using Fuzzy Set Theory. IEEE Transaction on Systems, Man and Cybernetics Part A: System and Human, Vol 26, pp. 493-496.

Deng H.(1999). Multicriteria Analysis with Fuzzy Pairwise Comparison. International Journal of Approximate Reasoning 21(3), pp..215-231.

Dominique Bérubé & Michel Jébrak (1999). High Precision Boundary Fractal Analysis for Shape Characterization. Computers & Geosciences, 25. pp.1059 –1071.

Herrera, F. and Verdegay, J.L. (1995). Fuzzy Sets and Operations Research Perspectives. Technical Report. Department of Computer Science and Artificial Intelligent; Granada, Spain.

Knight , Jeffrey L. (1997). GIS Based Compactness Measurement Using Fractal Analysis. George Mason University Fairfax, Virginia.

Laurini R. & Thompsom D. (1992); Fundamentals of Spatial Information System; Academic Press; London.

Mon, Don-Lin (1995). Evaluating Weapon System Using Fuzzy Analytical Hierarchy Process Based On Entropy Weight, IEEE, pp. 598-591.

Shiode, Narushige (1998). Towards Application Of GIS For Visualizing Fractal Phenomena; Center For Advanced Spatial Analysis; University College London.

Yeh C.H. and Deng H. (1997). An Algorithm for Fuzzy Multi-Criteria Decision Making. Proceedings of the IEEE First International Conference on Intelligent Processing Systems (ICIPS'97), pp. 1564 - 1568.

FROM URBAN LANDSCAPE TO INFORMATION LANDSCAPE

Digital Tainan as an Example

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Abstract. Urban landscape is an important visual form to reflect the characteristics of a city. This paper attempts to transform the urban landscape into information landscape to reveal the city characters, build a web-based system to navigate the 3D city model, and better understand the urban life by scene-based scenarios and role-play. The Digital Tainan project is presented for demonstration and discussion.

1. Introduction

Urban landscape is an important visual form to reflect the characteristics of a city, while different cities have their unique characters. We are concerned about the context of the physical city, the meaning and the structure of digital cities, and the interaction between the digital city and its users. We start with literature surveys of different city concepts in both physical and virtual cities, for instances, Sign City (Ockman, 1999), Collage City (Rowe and Koetter, 1978), Information City (Castells, 1991), Fractal City (Batty and Longley, 1994), City of Bits (Mitchell, 1995), Data town (MVRDV, 1998), and Virtual City (Dodge et al., 1998). These studies reflect the formation or representation of a city conceptually.

In a physical city, people can perceive the characteristics from its city landscape, and residents or tourists may have different city experience. While the urban is mainly shaped by its geographic properties, planning regulations, landmarks and infrastructures, the daily life and activities contribute mostly to the urban memory. Essentially, a city is a place for exchanging information. This study attempts to transform urban landscape into information landscape, and build a web-based system to navigate the 3D city model for better understanding the urban activities.

2. The Characteristics of a Digital City

What is a digital city? Mitchell (1985) depicts the city of bits as a result of digitalization, while a city generates and contains information for various reasons. In our opinion, a digital city is defined as a place for exchanging information and the physical form is only an expression of the city, while the spatial attributes remain critical for identification. A digital city should consist of various urban information created by the residents, and is interactive with its users. The contents and the characteristics of the digital city contribute to the formation of the city. Therefore, we use the information landscape to reveal the city information. "Information landscape" is defined to be a repository of information on the cyberspace and characterized by spatial attributes.

2.1 THE CONTENT OF A DIGITAL CITY

We have analyzed several digital cities, such as Virtual Helsinki, Virtual Seattle, Virtual Kyoto, Virtual Paris, etc. The common presentation of these digital cities is implemented on the web or CD-ROM to present the city information. Being a living environment, the main elements of the physical city are "activity", "space", "time", and "user".

Transformation of the physical city into the digital one can abstract the essence of the city information and enhance our understanding (Chiu, 1997). In the digital city, these elements are transformed into "information", "cyberspace", "sequence", and "role-play", Figure 1. Based on the relationship between information, cyberspace, and sequence, we are able to build a framework to represent the contents of information landscape.

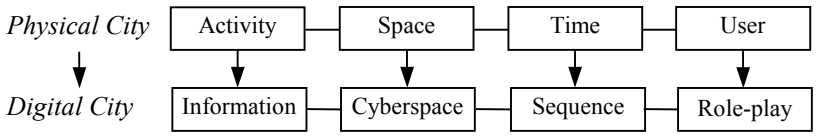


Figure 1. The elements transformed from the physical to the digital city

2.2 THE REPRESENTATION - CITY INFORMATION AND MEMORIES

Human are considered as urban information receptors on one hand, and reflect the scale and proportion, context, and experience of urban landscape (such as streets or buildings) from memory into various representations on the other hand. This study then analyzes what the digital city should looks like or what its representations are when users surfing a digital city on the web. In physical space, urban landscape has geographic attributes, and full

with natural and artificial objects. These objects can be represented by icons or artificial scenes with textural mappings (Chiu, et al., 2000). Thus, information landscape is a framework or platform with spatial attributes, while cyber-geography is somewhat different from the physical geography.

2.3 FUNCTIONS AND POTENTIAL USERS

A digital city on the web needs to be navigated, provide information to be searched, record memory, and interact with the users. Then the city model is created as an urban information system on the web and integrated with multimedia for storing, browsing and exchanging various information. Its application is toward a city information server for guiding people to experience the previous important events and current activities.

We suggest that the potential users of digital cities are not different from the real cities. While users can receive unique city experience in a physical city, users will get different experience when navigating a digital city. Users can take different roles in the digital cities at various period of time. The concept of 'role-play' is applied to the different users, such as citizen/foreigner, tourist/resident, male/female, young/old, and etc. For example, a young urban female professional worker has different perception and needs of the city information from an old male tourist.

3. Designing a Digital City

3.1 THE STRUCTURE OF THE DIGITAL CITY

The relationship between the physical and the digital city is classified as three types, i.e., replacement, complement or independence (Chiu, et al, 2000). We attempt to design the digital city with same content as the physical city, but represent the city by a new structure with existing information. The way is to take the existing physical city information apart, and reconfigure a new structure of the digital city. Figure 2 shows the 3D model of the physical city that consists of the original form.

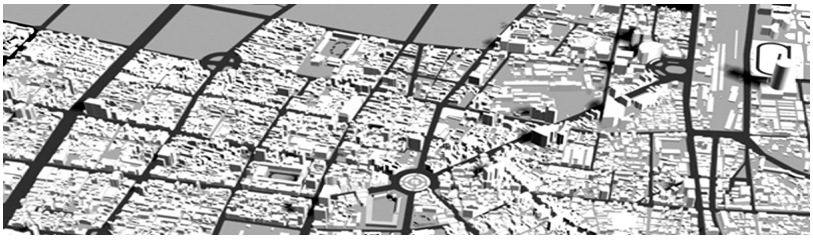


Figure 2. The 3D city model of the physical city

Figure 3 demonstrates the scope of geography and the details of information. We can classify the geographic information of the physical city and organize the digital city in three levels: city, zone, and building. Meanwhile, the details of information include site (or address), volume, context, and information (activities or events).

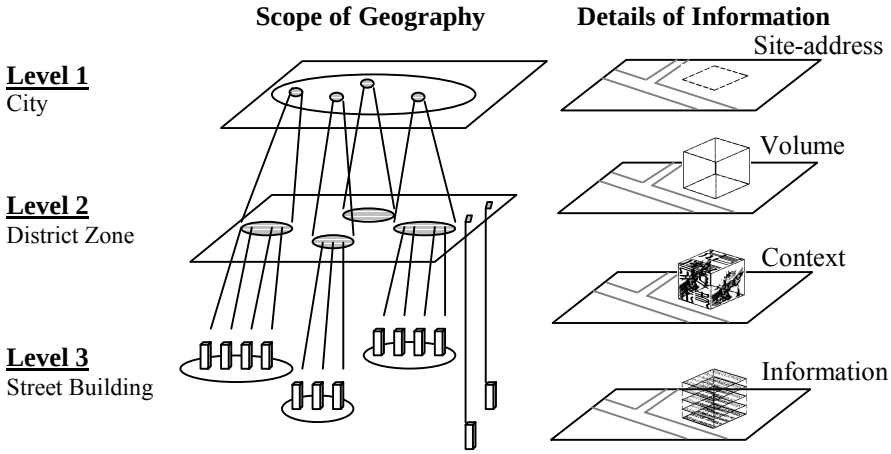
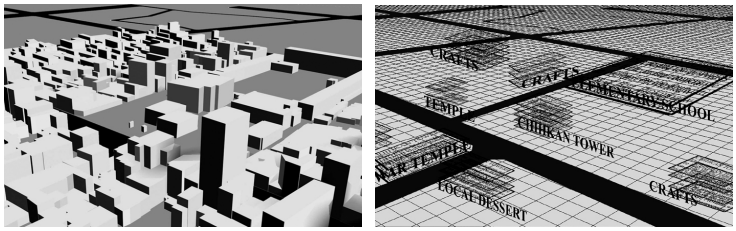


Figure 3. The structure of the digital city

3.2 DIGITALIZATION OF CITY INFORMATION

The system is mapping the locational attributes into a new structure with infilling of various information. We are concerned about what the messages are from the city information rather than the geometrical description of the physical form. Thus a small historic building may include more information than a skyscraper. Therefore, the city information can be digitalized and represented in different forms alternatively. For instance, Figure 4 illustrates the 3D city model on the left and the information landscape on the right.



3D City model Information landscape

Figure 4. The digitalization of city information

3.3 INTERFACE IN DIGITAL CITIES

We apply digital images, texts, 3D models, panorama views, animation, VRML, sounds to illustrate the different activities or experience. The web-based system is therefore integrated with these inputs. Meanwhile, the cognitive map of each user is unique to the others, and it reflects the personal experience and memory. Therefore, we attempt to enhance the interaction by recalling the visual and acoustical experience in accordance with the locations. The collaged urban images and sounds are provided for the users to construct their cognitive maps, such as visual maps and sound maps.

3.4 SCENARIOS AND ROLE-PLAY

The roles of users in the system are also concerned. The user may act as a tourist, a resident, or a researcher. Every user has his/her own way to read city information, therefore the users can choose their roles in the system for associating related information.

The scenario concept is also adopted to relate the cognitive maps to the different users. A scenario is defined as a play with scenes, roles, events, and time sequence, Figure 5. Therefore, users can define their roles in the play, such as citizen/foreigner, tourist/resident, male/female, young/old, and etc.

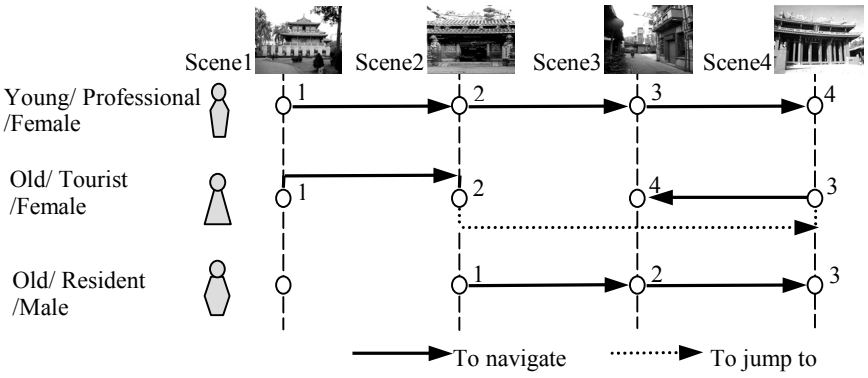


Figure 5. Role-play in a scenario

4. Demonstration of the Digital Tainan

Tainan is the oldest city in Taiwan with plenty of historic buildings and cultural heritages. The Digital Tainan is implemented as an example to illustrate the concept and for further discussion. This section presents the framework and demonstrations of the Digital Tainan project.

4.1 THE CONTENT AND REPRESENTATION OF DIGITAL TAINAN

The city of Tainan is decomposed into several component layers: city, zone, and building, and users can access the Digital Tainan by "search", "navigate", "explore", and "describe" functions. The user can discover his/her own interests in the Digital Tainan by choosing the different systematic layers of the city. The context of the Tainan city is integrated and represented by images, texts, models, maps, panorama images, animation, and sound. Figure 6 demonstrates the snapshots of the Digital Tainan.

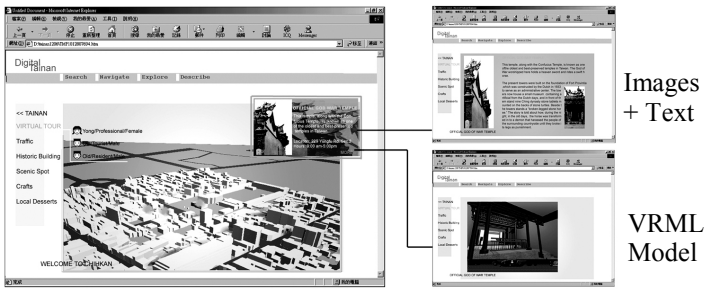
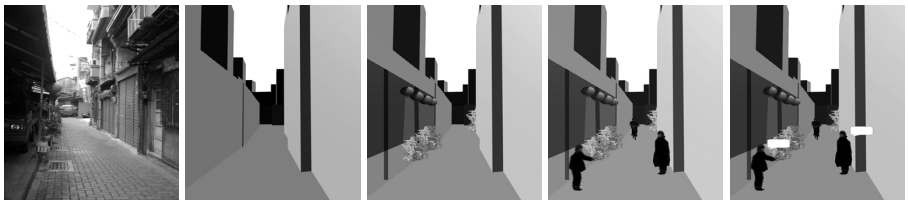


Figure 6. The presentation of Digital Tainan

4.2 NAVIGATION - STREET EXPERIENCE

From the behavioral point of view, we further study whether the city model can provide different city experiences to different users. Figure 7 illustrates the variation of a sequence of images of a typical street in the central Tainan. The scenes are represented in a sequence of buildings, plus signboards, walking people, and sounds to reflect different levels of city information, which the users can perceive the city images visually and acoustically.



a. Present scene b. street+ building c. +signboards d. +walking people e. +sound

Figure 7. Navigating with the different elements

4.3 EXPLORATION - BUILDING EXPERIENCE

Users can explore specific buildings or landmarks in-depth by panorama images or 3D animation of the particular building. For example, we use 3D

models to simulate the experience of visiting a historical site by change of the scope and angels of views. Figure 8 illustrates the sequence of exploring a particular historic building from the outside environment to the inside spatial relation.

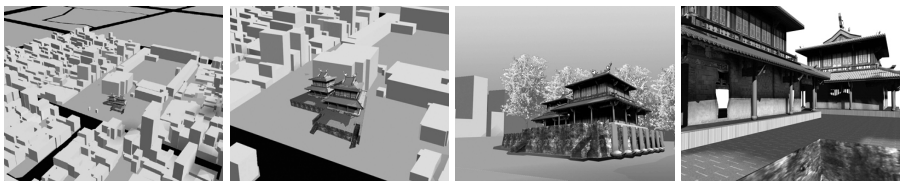


Figure 8. Exploration of a historical building from different views

5. Discussion

5.1 THE MEANING OF DIGITALIZATION

A digital city is a container with memories in the past and activity information at present to reflect the personal experience. Although we built the web-based city information system for promoting interaction, the emphasis of the digital city is to reflect the memories of the different users. The meaning of digitalization is to deliver the information of a physical city by a new platform, including all kinds of city messages, such as the image, sound, behavior and memories, not merely the form.

5.2 SOCIAL INTERACTION

The urban life is a social activity. City is a place for exchanging information, and social interaction is the way to proceed. In the Digital Tainan, we attempted to achieve the interaction by scenarios. But the way of scenario is confined to the passive interaction, and the users can merely choose the arranged roles and scenarios to navigate the information of the digital city. The further step is to design the interactive interface for allowing the users define their roles and interact with each others.

5.3 USER RESPONSE

After surfing the Digital Tainan on the web, we found that users in different backgrounds have variant interests. For example, a tourist is generally interested in navigating the visual representation and the acoustical experience of the tourist spots, and the design interface created by multimedia provide a mean for interaction. However, a professional may

explore the spatial experience and the details by search the background information first and access related links. Therefore, an information bank (including image, sounds, and digital models) is necessary for organizing various digital city information.

5.4 FUTURE WORK

The transformation of urban landscape into information landscape requires methodological as well as technological efforts. Currently, most digital cities exist are mainly created as a repository or an information bank. The Digital Tainan project provides some directions for future development in the design of the digital cities, including information, user behaviors, and technologies. The scenarios used in the system reflect some social behaviors, while limited roles are defined. Therefore, the social interaction requires more in-depth studied and integration of technology to reach the intention.

References

Batty, M. and Longley, P.: 1994, *Fractal Cities*, Academic Press

Chiu, M.L., Lan, J.H., 2001, Discovery of Historical Tainan: A Digital Approach, *Automation in Construction*, Vol.10, No.3, pp.355-364

Chiu, M.L., Y.T. Lin, K.W. Tseng, C.H. Chen: 2000, Museum of Interface: Designing the virtual environment, *Proceedings of the Fifth International Conference of CAADRIA '2000*, Singapore, pp.471-480

Chiu, M.L.: 1997, Transforming The Reality into Virtual Reality - The Influence of Computer Simulation Technologies on the Built Environment, *Proceedings of The Seventh International Conference on Computing for Civil and Building Engineering* (ICCCBE), Vol. 1, Seoul, Korea, pp.659-664

Castells, Manuel: 1991, The Informational City: Information Technology, Economic Restructuring, and the Urban-Regional Process

Cybergeography, An Atlas of Cyberspaces, URL at http://www.cybergeography.org/atlas/

Helsinki Arena 2000: URL at http://www.helsinkiarena2000.fi/

Horan, Thomas A., Mitchell, W. J.: 2000, Digital Places: Building Our City of Bits, MIT Press

Lynch, K.: 1960, The Image of the city, Technology Press

Mitchell, W.: 1995, *City of Bits*, The MIT Press

MVDRV: 1998, Metacity / Datatown, URL at http://www.mvrdv.archined.nl/datatown/index.html

Ockman, J.: 1999, *From Sin City to Sign City*, A+U 344, 6-11

Rowe, C. and Koetter, F.: 1978, *Collage City*, The MIT Press

Virtual Cities: URL at http://64.33.103.244/high/index/index.html

CONSTRUCTION OF DIGITAL CITY IN PHYSICAL CITY

Cyberspatial Cognition Approach to the project of HsinChu digital city in Taiwan

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Abstract. The cyberspace upon physical space forms a new spatial structure to increase the influence on the urban fabric and the concept of space in architecture. Today, digital cities are being developed all over the world. By using a city metaphor, digital cities integrate urban information and create public spaces. How do digital cities directly connect to physical cities and become an imaginable city? Therefore, we argue that a new spatial analysis theory must be established for digital city, comparing with theories of disciplines, to find the explicitly spatial structures and relations in digital city upon physical city.

1. Introduction

The cyberspace upon physical space forms a new spatial structure to increase the influence on the urban fabric and the concept of space in architecture (Mitchell, 1995, 1999; Liu 2001). Researchers from other field, such as geography (Dodge and Kitch, 2001; Kwan, 1999; Batty; 1997), sociology (Weber, 1995; Castells, 1998) and urban logy (Hall, 1998) studies, identify different overall frameworks of cyberspace to interpret the relation between the place we live in and the cyberplace we also live in. In architecture, the concept of design emerges a tendency to define, create and construct the digital architecture or space, not yet virtual, for the digital age (e.g., the 2000 and 2001 Far Eastern International Digital Architectural Design Award). The digital concept is already causing traditional building types to fragment, and form startling new landmark or skyline in cities (Mitchell, 2000).

More and more architectural scholars attempt to well define and inter-pret the nature of cyberspace (Huang, 2000, 2001; Wong et al, 2001; Liu, 2001).

Expecting to explicitly redefine architectural theory and interactively reconstruct the city space to be the digital city. Today, digital cities are being developed all over the world. By using a city metaphor, digital cities integrate urban information and create public spaces for people living in the cities (Toru Ishida, 2000), and provide an opportunity to people to create a new information space for their everyday life. How do digital cities directly connect to physical cities and become an imaginable city? We need map not just to navigate but to define and control new territory. The cyberspatial cognition approach in studying spatial structures of cyberspace and digital cities is an important access. Interestingly, the most studies of cyberspace and digital cities are influenced by the spatial knowledge of cognitive mapping (Theresa Duncan, et al, 2000; Kheir Al-Kodmany, 2001; Dodge and Kitch, 2001; Kwan, 1999), which has developed by Lynch (1960).

A more subtle point is that we need to consider the mappings of the digital to the physical and the physical to the digital. According to Mitchell (1999), the physical city and digital city also can combine together and convolution to form a new urban topology. But how to analyze and combine digital city and physical city, and how to describe the spatial structures of digital city, this is unknown knowledge domain, not like digital architectural designs. Therefore, we argue that a new spatial analysis theory must be established for digital city, comparing with theories of disciplines, to find the explicitly spatial structures and relations in digital city upon physical city.

The first step of this research is to introduce the four type theories of interpreting spatial structure on the physical and digital cities. The second step comprises an existing digital city Kyoto (http://www.digitalcity.gr.jp/) and the project of HsinChu digital city in Taiwan. In the end, the two types of digital city will be compared in order to find out the relation between digital city and physical city.

2. Methodology

In order to understand the spatial phenomena in the cyberspace represent an important challenge for urban scholars and architectural analysts. We will refer to different theories on physical and digital city. Then we will visit the two types of digital city and emphasize how the projects each relate to the urban fabric and image.

2.1. THE PERSPECTIVE OF DIFFERENT THEORIES

In this section, we combine four types of describing spatial structures, like the following (table1), to explore the influence upon spatial structures between physical city and digital city. Lynch's (1960) analysis of the city rested on five

different elements: paths, edges, landmarks, nodes, and districts, to image the physical city form as the mental map. Lynch provided a theoretical framework for studying cognitive maps, urban form, and the spatial relationships of cities. This included an exploration of how regular citizens use and visualize city spaces. An imageable city helps residents and visitors better to orientate themselves spatially, to navigate through the city, and to find their way. In Lynch's framework, Kheir (2001) argue that one could view a city as a web of paths and nodes that are surrounded by edges and contain districts and landmarks.

On the social view, describing the so-call space of flows to gain the spatial imagination by three layers of material: a circuit of electronic impulses, computer processing and high-speed transportation; the nodes and hubs of Networking; and the spatial organization of the dominant elites (Castells, 1992). The theory of Mapping-Cyberspace emphasizes the physical infrastructure, traffic flows, the demographics of the new cyberspace communities (Dodge and Kitch, 2001), to the perception and visualization of these new digital spaces. The recent research as Liu (2001) on digital space found that the three core elements of both verbally and visually constructed virtual space: movements, interactions and acoustic effects. We explore the relation among different theories. Then we base on cognitive map to synthesize and find out the network of their spatial concept (figure1).

Table 1.Theories of the spatial structures about physical space and digital space

Kevin Lynch (The Image of the City)	Manuel Castells (Space of Flows)	Martin Dodge (Mapping-Cyberspace)	Yu-Tung Liu (Digital Space)
1.Paths 2.Edges 3.Landmarks 4.Nodes 5.districts	1.A circuit of electronic impulses, computer processing and high-speed transportation 2.The nodes and hubs of Networking 3.The spatial organization of the dominant elites	1.The physical infrastructure 2.Traffic flows 3.The demographics of the new cyberspace communities	1.Movements 2.Interactions 3.Acoustic effects

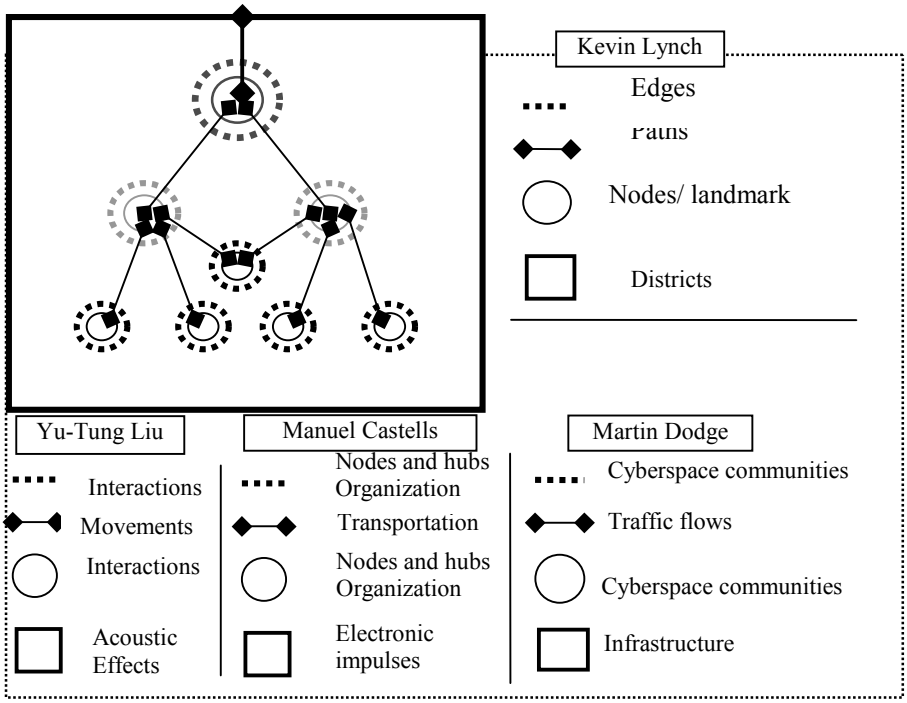


Figure1. Figure the network of their spatial concept

2.2. VISITING THE TWO TYPES OF DIGITAL CITY

2.2.1. The Digital City Kyoto

This project developed a digital city prototype as a social information infrastructure for Kyoto in 1998. The Digital City Kyoto (Figure 2) performed a city metaphorical form: a 2D map and a 3D virtual space. A large number of WEB pages (2600 in September 1999) are being collected and linked to the 2D/3D city (Toru Ishida, 2000). Real-time mapping data from the physical city is also mapped to the digital city. As the human interface, a whole Shijo street (2Km long) has been implemented to simulate the city environment in a 3D virtual space. Citizens or visitors can get information related to the physical city such as traffic, weather, parking, shopping, and sightseeing. Digital City Kyoto had the social interaction among residents and tourists. For oversea visitors via the Internet, Digital City Kyoto had provided a digital bus tour with a guide agent that supports cross-cultural communication.

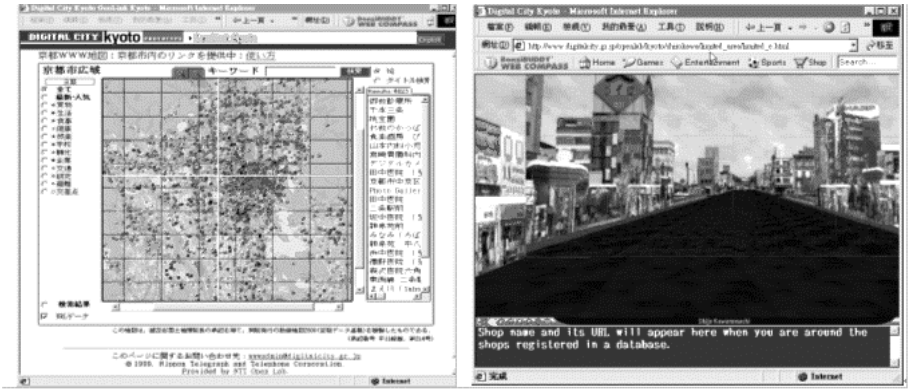


Figure 2. Digital City Kyoto http://www.digitalcity.gr.jp/.

2.2.2. The Digital City HsinChu

This project initially started to develop the Hsinchu Art Museum in 1999. But the key planner, Liu (2000), hope to create a masterpiece encompassing historical heritage at the digital age for the city of Hsinchu, with her 170 years of history and strength of computer technology. Therefore, the Digital City Art Center had being form to conduct the future of Hsinchu city. The project emphasized how to translate the urban underlying traffic and building into the digital city underlying network and digital media. At the digital era, this project developed a digital city prototype as a new spatial structure and landmark for Hsinchu. Digital City Hsinchu makes available different city image and percept: by building a physical and digital architecture to expand the spatial image of digital city and connect the network of new urban fabric environment (Figure 3). Thus the Digital City Hsinchu perform a hierarchical network of spatial structure to drive the digital development of architecture and urban.

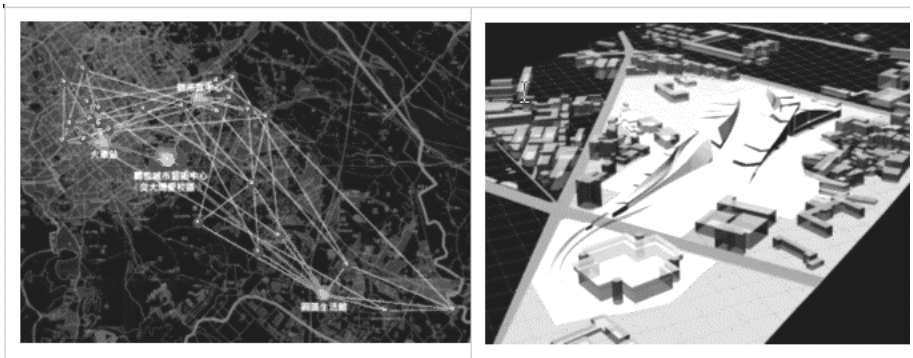


Figure3. The Digital City HsinChu http://www.arch.nctu.edu.tw

3. A comparative analysis

The concept of digital or information cities is the flows of network. From the compare and synthesis of the four different theories, we can map the most important spatial concepts, which are paths, nodes and landmarks, of digital cities and cyberspace. Anyway, the physical, digital or cyberspatial cities all need a cognitive map of spatial concepts for the visitors and residents. The greater part researches of cyberspatial cognition usually quote the Lynch's research of the mental map theory to find orientation. Besides, the impact of digital concepts on architecture, a new startling form by computational design and manufacture, has evolving and liberating concept of space and form. In digital era, the new architectural form have impacting on the past image of spatial cognition and urban fabric (Liu, 2000). When the phrase of digital city emerge, not alike information city, it imply the two above-mentioned digital concepts. However, the most so-call digital cities are based on cyberspace (web-space) to simulate the image of physical environment and the relation of interaction. There has a tendency toward (Lin, 2001): the definition of Digital City is based on the hardware and software of information, telecommunications and network to lay special emphasis on urban infrastructure. The definition of Informational City is to provide the citizen-oriented information service and content about urban. Otherwise, combining with the above both to develop cybercities or virtual cities, as Helsinki Arena 2000 Project. However, all of the above can not let people to exactly perceive the special impact on the physical city in digital era, as modernism formed the image of a city. The cyberspatial concept between The Digital City Kyoto and The Digital City HsinChu both have the components of hierarchical nodes, paths, landmarks, edge and district by two or three dimensional maps images (Figure 4 , 5).

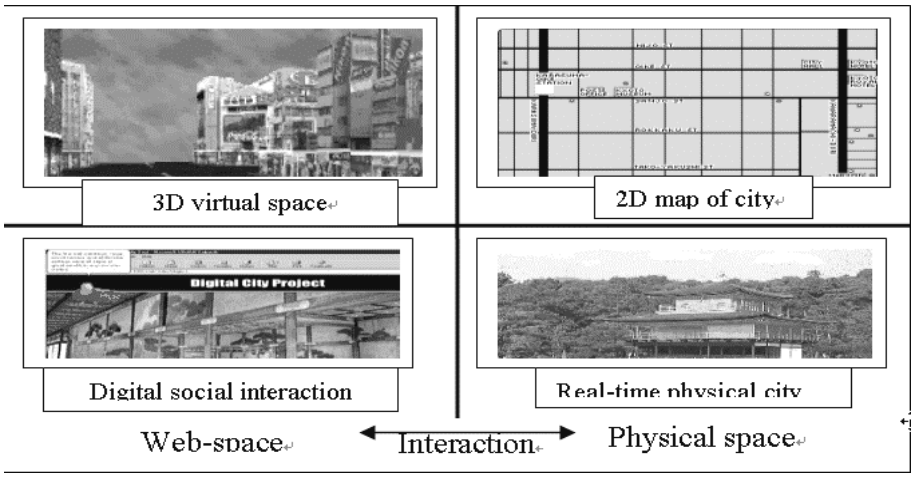


Figure4. The metaphors of the Digital City Kyoto

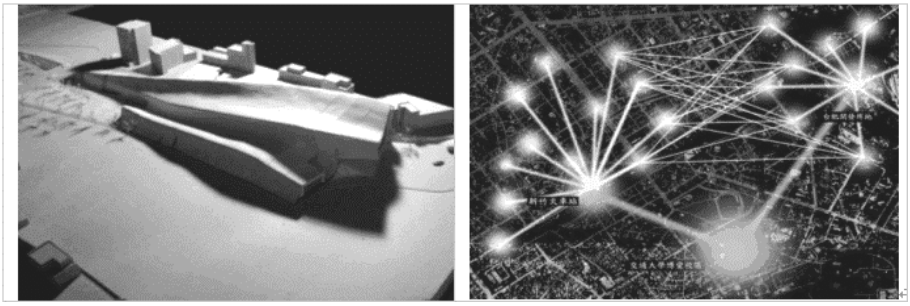


Figure5. The new fabric environment of The Digital City HsinChu.

The difference of both digital cities is that The Digital City Kyoto performed digital concepts that simulated, and virtual Kyoto city to create the duality of Kyoto city. However, the urban fabric and the image of space are almost constant. The Digital City HsinChu performed digital concepts have attempted to create a new cognitive image of urban space. By arranging the buildings of digital design on different nodes, The Digital City HsinChu have changing and forming a new image of the city and spatial structure to let residents perceive the meaning of urban space in digital era. In addition, this project had proposed a concept of virtual city to co-construct the digital duality from physical and virtual cities.

4. Conclusion

The results of this research indicate that the relation between digital city and physical city is not a dichotomy but extending the definition and boundary of city space by interacting and constructing in each other. At the same time, providing architectural and urban designers might benefit from the outline of analysis framework. In addition, a theoretical comparison among the five elements of the city, the space of flows, mapping-cyberspace and digital space interpreted space are explored for constructing the digital city in the physical city. Finally, further studies related to the construction of digital city in physical city are how to study the impact on the spatial cognition of urban fabric by digital concept, not only the cyberspace.

Acknowledgements

I sincerely express the great appreciation for Professor Yu-Tung Liu. His constructive comments on earlier versions of this article sparked exciting concept about digital cities and their future.

References

Batty, M.: 1997, Virtual geography,Future,No.4/5,vol.29,pp.337-357.

Batty, M.: 2001 Contradictions and conceptions of the digital city, Environment and Planning B: Planning and Design, 28(4), pp. 479-480.

Chen, C. N.: 2000, Changing spatial imaginations in modern Taiwan and postmodern geography: A preliminary survey, *Manuscript at NCTU*, Hsinchu, Taiwan

Castells, M.: 1998, THE INFORMATION AGE: ECONOMY, SOCIETY AND CULTURE, VolumeIBlackwell, USA.

Dodge, M and Kitchin, R: 2001, Mapping Cyberspace, Routledge, London and New York.

Feng-Tyan Lin, 2001: Formulating an informational city: a case study of Kaoshiung, the urban planning conference, Korea.

Huang, C.H.: 2001, A Preliminary study of specializing cyberspace, Gero, J.S., Chase, S.and Rosenman, m. (Eds), CAADRIA2001, Key Centre of Design Computing and Cognition, University of Sydney, pp.27-37.

Kwan, M.P.:2001, Cyberspatial cognition and individual access to information: the behavioral of cybergeograghy, Eviroment and PlanningB: Planning and Design, vol.28, pp.21-37.

Kheir Al-Kodmany: 2001, Supporting imageability on the World Wide Web: Lynch's five elements of the city in community planning, Environment and Planning B: Planning and Design 2001, volume 28, pages 805 ^ 832

Lynch, K.: 1960, The Image of The City, MIT Press, Cambridge, MA.

Liu, Y. T.: 2000, The evolving concept of space: From Hsinchu Museum of Arts to Digital City Art Center. *ACADIA Quarterly* 19, no. 4.

Liu, Y. T.: 2001, Defining Digital Architecture: The 2000 FEIDAD Award. Taipei: Dialogue.

Maher, M. L.: 1999, Design the virtual campus as a virtual world, *Proceedings of CSCL 99*, Standard University, pp. 376-382.

Mitchell, W. J.: 1999, Replacing place, *in* P. Lunenfeld (ed), *The Digital Dialect: New Essays on New Media*, MIT press, Cambridge, MA. pp. 112-128.

Mitchell, W. J.: 1995, *City of Bits*, MIT Press, Cambridge, MA.

Hall, P.:1988, CITIES IN CIVILIZATION: Culture, Innovation, and Urban Order, London, WC2H9EA.

Strate, L.: 1999, The varieties of cyberspace: problems in definition and delimitation, *Western Journal of Communication*, 63: 382-413.

Wong, C.H., Liu, Y.T., Chen, S.C.:2001, Is Cyberspace A Space? A preliminary exploration of the spatial phenomena in the internet, Gero,J.S.,Chase,s.and Rosenman,m.(eds),CAADRIA2001,Key Centre of Design Computing and Cognition, University of Sydney,pp189-194.

Webber, F: 1995, Theories of the Information Society, Routledge.

Toru Ishida: 2000, Understanding Digital Cities, In T. Ishida and K. Isbister Eds. Digital Cities: Experiences, Technologies and Future Perspectives Lecture Notes in Computer Science, Vol. 1765, Springer-Verlag, 2000.

A PLACE WHERE PEOPLE ARE FREE TO MOVE:

Exploring dynamic texture mapping in computer graphic systems

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Abstract. Recent studies, both collaborative design system and scenario scripting, attempt to explore further CG media. Corbusier pointed out that good architecture is a place where people can walk unrestrainedly and feel free in spirit. However, it is apparent that the human figures are still in animation, whereas they are free to move in the real world. The human figure always plays an important role in the development of design media. The objective of this paper is to develop a new design method using CG media and to study the process of dynamic human texture mapping within the CG. This research conducted a design experiment using computer as the sole design medium. The results show that the new design method not only altered the behavior of the designer, but also impacted design thinking cognition.

1. Introduction

Many studies has been undertaken in respect to the importance of design media, which evolved from text, drafting, modeling, to applications of recent digital technology (Hewitt, 1985; Koch, 1997; Goldschmidt, 1999). Different media cause different impacts to various stages of the design process (Krawczyk, 1997; Maher, 1999). In particular, research topics focusing on the involvement of computers in the design thinking process have become more and more mature, to gradually form a new way of design methods (Liu, 1996). Therefore, multimedia design has especially become a popular topic of research (Lin, 1999; Dave, 2000), containing three main directions: computer graphics (CG); the Internet; and virtual reality (VR). Researchers were interested in studying how these media might aid the designer significantly in the concept stage of design and communication (Madazo, 2000; Haymaker, 2000). Within these three directions, CG

technology has developed to an extent, thanks to it's ability of accurate and realistic simulation (Lin, 2001; Huang et al., 2001). However, due to limitations in bandwidth, applications of Internet technology in architectural design including collaborative design and database processing systems are still limited (Murray, 1997; Jozen et al., 2000). Moreover, the facility of VR simulator such as VR Cave is still over-expensive therefore the cost prohibits the development of this research (Knight and Brown, 1999; Fukuda, 2001).

Based on the ability of producing accurate and realistic representation, CG technology has increasingly enhanced the potential for interaction between human and design. In the book Architectural Principles in the Age of Humanism, it was emphasized that the perceptions of experience in space change as soon as human bodies move (Wittkower, 1971). In addition, Le Corbusier pointed out that good architecture is a place where people can walk unrestrainedly and feel free in spirit (Jenger, 1987). However, recent studies, both applying CG technology to collaborative design system for citizen participation (Sasada, 2000) and combining the use of animation and scenario scripting (Huang, 2001), attempt to explore further CG media. However, it is apparent that the human figures are still in animation, whereas they are free to move in the real world. The human figure always plays an important role in the development of design media. Evolved from the sketches, plans, elevations, image processing, animation, and virtual reality, the purpose of the appearance of human figure is to emphasize representation of human existence, in order to convey a more vivid description of design concepts and even the interaction between human and space (Panofsky, 1960). The objective of this paper is to develop a new design method using CG media and to study the process of dynamic human texture mapping within the CG.

2. Experiencing and Exploring Space

In order to examine the differences between traditional and dynamic texture mapping, this research conducted a design experiment using computer as the sole design medium. This research consists of four steps. First of all, computers were used to produce two identical digital sites, applying dynamic texture mapping methods in one scene and traditional one to another. Second, two designers were chosen as the subjects on an equal basis of their knowledge and expertise in respect to computer operation in 3D environments. Then show the animation of site introduction with dynamic human texture mapping to one subject, and without dynamic human texture mapping to another. In the third step, the subjects were asked to produce a simple design in each given site. The aim was to examine and

record differences arising from design cognition. Finally, an analysis of the experimental data was discussed including various comparisons of the two data types.

In order to emphasis the importance of human movement, we conducted an experiment of remodel design. The task of the experiment is to renew an old museum, which has many problems of original design such as the height of interior is over high, the distance of circulation is too long, and the exhibitive rooms are bad for use as well as the quality of lighting. Therefore the theme of the design task is how to improve the visiting circulation and the relation between users and exhibitions. Museum design has a great requirement of function, so the design task was divided into three parts, including the arrangement of circulation, the concept of entry hall, and the detail of an exhibitive room design (Figure 1). The design condition is very flexible, and the subjects can remove or add the wall freely.

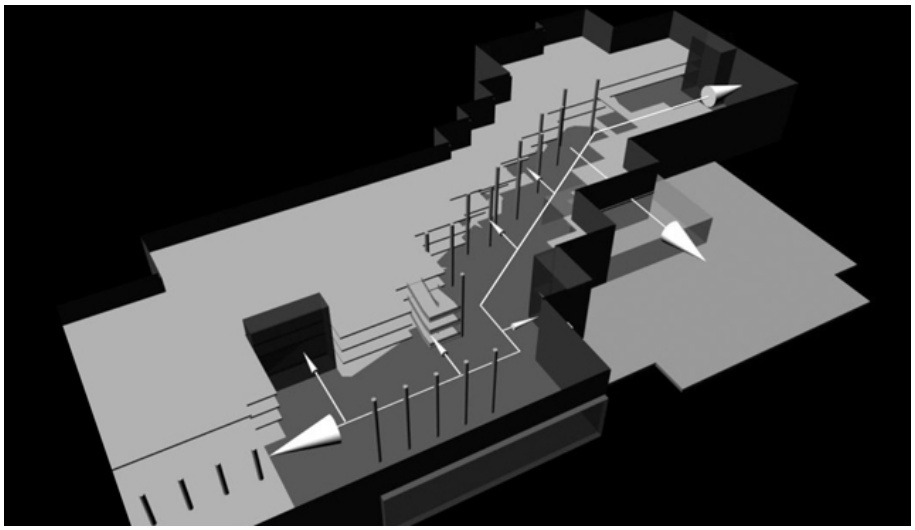


Figure 1. Circulation arrangement of site by subject.

3. Analysis and Results

3.1. THE CONVENTIONAL DESIGN

In examples taken from the design of sites in respect to conventional design, it can be seen that the design first made use of a corridor as a means of dividing the lengthwise space in half; and this being completed, proceeded

to carefully organize a system of circulation, a system that involved the use of ingenious methods to join the various parts into a single entity. From the means used to design this edifice, as expressed in its form, we can identify it as being modernist in it inherent spatial tendencies. And in considering the over-all mass of the building, it can be seen that the sense of grandeur that characterizes its over-all atmosphere, has been successfully replicated. Moreover, in regard to the vertical spaces, and the over-all sense of scale of the interior of the building, that is a building intended to embody a form representative of a mythical palace of art, the majesty and elegance of the feeling of the design as a whole has been successfully expressed (Figure 2).

3.2. DESIGN WITH DYNAMIC TEXTURE MAPPING

In respect to the use of dynamic human texture mapping for site design in respect to the design of the middle interior spaces of a public building, or public hall, the means by which the various exhibition spaces were connected together in respect to their left right-axis, and in particular, the fluency and coherence of the system of circulation, was the aspect of design given most emphasis. Thus, the localized interior spaces were designed in a manner that related well to the exterior constructions on the site, as well as serving the multi-level function of the park and museum. The structural elements of the design included a system of outwardly radiating spaces, and in this regard the design enables the user to become aware of the sense in which the works of art and the viewer are able to coexist in a single space. Of particular importance is the degree of transparency built into the design, so that in this way the user is able to both experience a sense of inter-reaction with the design as a whole and with other users of the design (Figure 3). Moreover, the means of displaying art works was designed in a manner demonstrating a careful and systematic attention to detail.

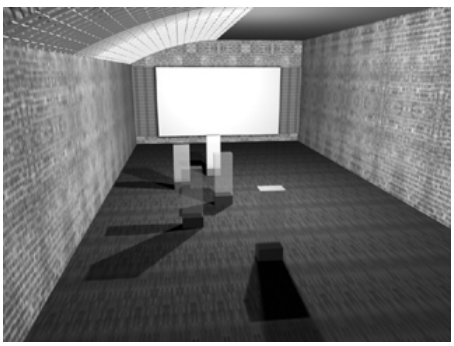


Figure 2. Exhibitive design of subject A.

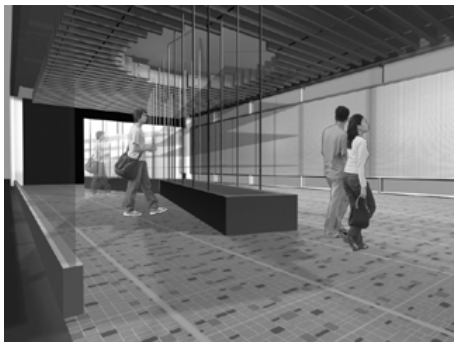


Figure 3. Exhibitive design of subject B.

4. The Impact of Human Movement

In arranging the circulation, the subject who was introduced the site without dynamic human texture mapping (subject A) focused on the appropriateness of relations within the over-all system of circulation, whilst the another subject (subject B), in organizing the over-system of spatial relationships, dealt with circulation as it existed in respect to people. As regards the interior space, a used art design as a basis for analysis; and subject B also made use of art design in this respect, but additionally, focused on the inter-relationships of users, as well as the relationship of the cognitive process of the users and the works of art on display. Subject B was able to supply a sense of space that as well as being lively, displayed a fairly high degree of richness and freshness of design. In regard to the scale of the design as perceived by its users, subject A had no problems in arriving at a design built with a system of scales well suited to the visual judgment of the user, whilst subject B was more successful in respect to scale as it exists in relation to the activities and movements of the user. In regarding the relationship of people and culture as seen from a wider perspective, subject B showed an ability in its management of space, to allow for a careful consideration of human possibility, and in meeting the needs of users generally, and in this way was better able to obtain a sense of intimacy between people and architectural space (Figure 4), whereas subject A focused more on the dynamics of inter-relationships, thus creating a sense of over-all design.

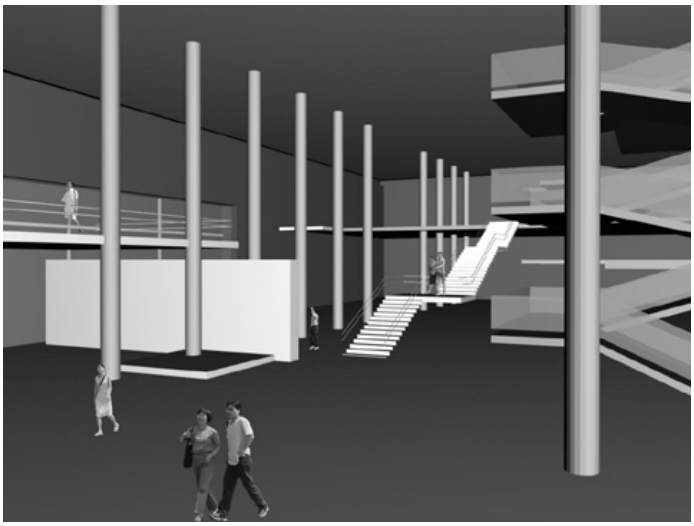


Figure 4. A careful consideration of human possibility.

5. Discussion

The research shows that the new design method not only altered the behavior of the designer, but also impacted design thinking cognition. Operating in an environment that can simulate human movement, designers are able to draw on a much richer source of visual data to organize spatial patterns, manipulate design situations, and produce design concepts. Future research, based on above findings, would involve applications of the dynamic texture mapping technology to the standardized 3D software currently available.

References

Dave, B.: 2000, Architecture of digital imagination, *Proceedings of the CAADRIA 2000*, 297-306.

Fukuda, T. (ed.): 2001, Collaboration Support System for Nightscape Design Based on VR Technology, *Proceedings of the CAADRIA 2001*, 103-111.

Goldschmidt, G.: 1999, On Visual Design Thinking: the vis kids of architecture, *Design Studies*, 21(2), 158-174

Haymaker, J.: 2000, Filter Mediated Design: generating coherence in collaborative design, *Design Studies,* 21(2), 205-220.

Hewitt, M.: 1985, Representational Forms and Models of Conception, *Journal of Architectural Education: JAE*, 39(2), 2-9

Huang, Y. H. (ed.): 2001, Scenario Scripting in the Design Process, *Proceedings of the CAADRIA 2001*, 231-239.

Jenger. J.: 1987, *Le Corbusier: Architect of a New Age*, Thames and Hudson, New Horizons

Jozen, T. (ed.): 2000, The Concept Network Model Database, *Proceedings of the CAADRIA 2000*, 379-388

Knight, M.: 1999, Working in Virtual environments through appropriate physical interfaces, *Proceedings of the eCAADe 1999*, 431-436.

Koch, M.: 1997, Interview Peter Eisenman: a post-structural architect, *Dialogue*, 9, 34-43

Krawczyk, R. J.: 1997, Representation and design, *ACADIA*, 95-109

Lin, C. Y.: 1999, The Representing Capacity of Physical Models and Digital Models, *Proceedings of the CAADRIA 1999*, 53-62.

Lin, C. Y.: 2001, A Digital Procedure of Building Construction, *Proceedings of the CAADRIA 2001*, 53-62.

Liu, Y. T.: 1996, *Understanding of Architecture in the Computer Era,* Hu's, Taipei

Madrazo, L.: 2000, Computer and architecture design: going beyond the tool, *Automation In Construction*, 9, 5-17

Maher, M. L.: 1999, Designing the virtual campus, *Design Studies*, 20(4), 319-342

Murray, J.: 1997, *Hamlet on the Holodeck: the future of narrative in cyberspace*, The Free Press, New York.

Panofsky, E.: 1960, *Renaissance and Renaissances in Western Art*, Harper and Row.

Sasada, T.: 2000, Computer Graphics and Design: Presentation, Taiwan.

Wittkower, R.: 1971, Architectural Principles in the Age of Humanism, Wiley, NY

BRIDGING THE GAP BETWEEN BUILDING SCIENCE AND DESIGN STUDIOS

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Abstract. Design studios and building science courses have been conducted independent of each other, mainly due to a lack of tools that allow quick and easy consideration of building science criteria, such as comfort and energy requirements, during the design process. Existing tools are not user-friendly and their use requires significant effort in gaining familiarity with the input requirements, understanding the modeling assumptions and interpreting the output. This paper is about the Building Design Advisor (BDA), an evolving computer-based tool intended to bridge the gap between design studios and building science considerations by addressing the above-mentioned limitations of existing tools. BDA allows automatic preparation of input files to multiple simulation tools while the user is working in a CAD environment. BDA automatically activates the relevant simulation tools when the user selects performance parameters to be computed and provides the results in a graphical form, allowing comparison of multiple design options with respect to multiple performance criteria. The paper includes considerations for the use of the BDA in the design studio and ends with a description of the current development efforts and future plans.

1. Introduction & Background

Building design studios in most architectural education programs focus mainly on the spatial functionality and the overall form and aesthetic appeal of the building, neglecting the consideration of other performance aspects, such as comfort, cost, energy efficiency, environmental impact, etc. Such considerations are becoming increasingly important in the building industry and, to be effective, they need to be integrated into architectural design from the initial, schematic phases of building design.

Most architectural education programs include building science courses that address performance aspects such as comfort, energy, and environmental impact. These usually include design "exercises" which allow students to better understand concepts, principles, methods and tools. However, they usually focus on a few criteria that reflect the subject and scope of the course, neglecting the spatial arrangement and aesthetic issues.

Currently, there is a lack of courses that allow for integrated building design through consideration of multiple performance criteria, i.e., integrating consideration of comfort, energy, cost, environmental impact, etc., in the traditional architectural considerations of spatial arrangement and aesthetic appeal. The lack of such courses is a reflection of traditional architectural practice, which however is changing, as we become increasingly aware and better informed about the impact that buildings have on our lives, as well as the strategic and technological means available for the design of better buildings.

1.1 TRADITIONAL ARCHITECTURAL PRACTICE

Traditionally, architects have been involved with the initial formulation of the building design, focusing on the arrangement of the spaces called for by the architectural program, in a way that produces a functional and esthetically pleasing building design.

After most of the architectural design is in place, it is passed on to engineers, who address structural, mechanical, electrical, etc. issues and specify building envelop components and mechanical systems that address the heating, cooling and ventilation needs of the building to provide comfort and indoor air quality. However, if heating, cooling, lighting, etc. were considered from the initial, schematic phases of building design, the resulting building design could have significantly reduced loads, providing increased comfort at reduced cost, e.g., by reducing the size of mechanical and electrical equipment.

1.2. BARRIERS TO INTEGRATED BUILDING DESIGN

Unlike spatial arrangement and aesthetic appeal, which can be evaluated directly from the traditional architectural drawings, most building science performance considerations such as thermal, luminous and acoustic comfort, energy requirements, environmental impact, etc., require significant effort for the computation of the values of relevant performance parameters.

To address such computation requirements, a number of computer programs have been developed, usually referred to as simulation programs, such as DOE2.1E (Birdsall et al. 1990), TRNSYS (Klein et al. 1976), Radiance (Ward and Shakespeare, 1998), Lumen Micro

(http://www.lighting-technologies.com/), COMIS (Feustel, 1998), Athena (Trusty and Meil, 1997), etc.

Most simulation programs have been developed by researchers for research purposes and do not have an intuitive user interface. They require the development of input files that contain the description of the building environment and its operation blending key words and values in carefully organized formats. Moreover, they provide output in the form of alphanumeric tables that are not easy to review and interpret.

Most of the available simulation tools, especially the ones that have advanced modeling capabilities and increased performance prediction accuracy, require detailed descriptions of the building and its operational characteristics, such as construction specifications, occupancy patterns, operational schedules, etc. This type of detailed information is usually not addressed during the early, schematic phases of architectural design, when the focus is mostly on spatial arrangement and aesthetic appeal.

2. The Building Design Advisor (BDA)

The Building Design Advisor is a software tool designed to help overcome the barriers to integrated building design, by making the use of multiple simulation tools quick and easy from the initial, schematic phases of building design. The BDA uses a single, object-oriented representation of the building and its context, where building components and systems are described as inter-related objects that are characterized by lists of parameters (Papamichael et al., 2000).

The BDA software supports links to any number of simulation tools. The current version includes links to DElight (Hitchcock, 1995), a daylighting simulation tool; ECM, an electric lighting simulation tool; and DOE-2, a whole-building energy simulation software (Birdsall et al., 1990).

2.1 USING THE BDA SOFTWARE

The first step to modeling a building in BDA is to specify a project name, a user name and the building type and location. The last two pieces of information are used to determine "smart" default values for non-geometric parameters that are required as input to simulation tools, such as occupancy schedules, weather data, construction types, etc. Weather files follow the TMY2 format (http://rredc.nrel.gov/).

As soon as these project data are specified, the BDA software activates the Schematic Graphic Editor (SGE), which is a simple CAD environment that uses an object-oriented representation of building components and systems. SGE allows users to quickly and easily draw spaces, windows,

overhangs, vertical fins, external obstructions and lighting fixtures, as well as work-plane illuminance points for daylight-based electric lighting controls (Figure 1).

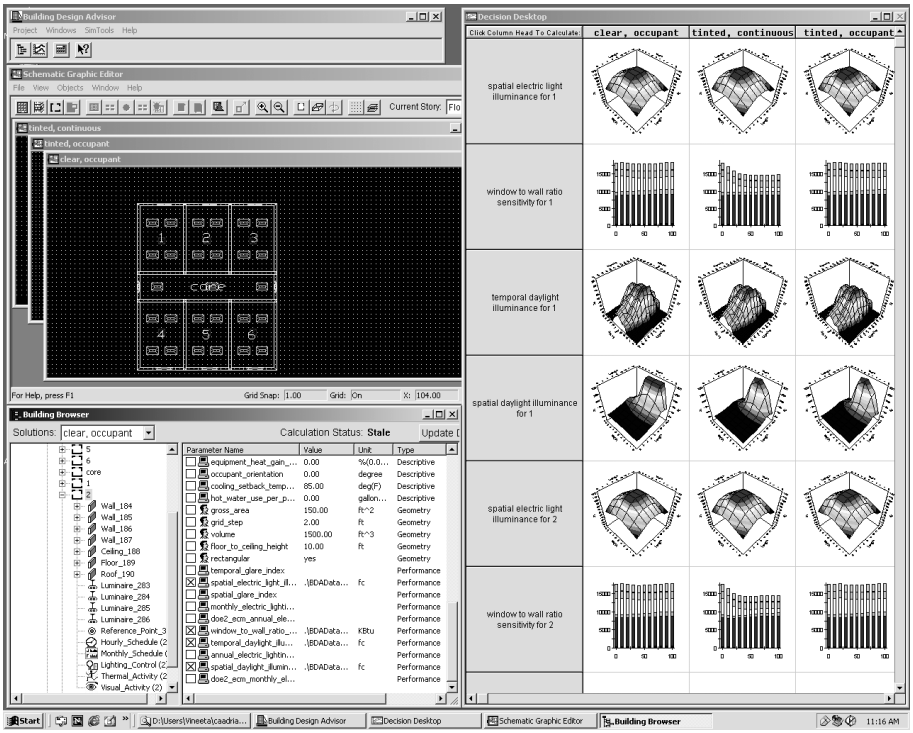


Figure 1. Screen shot of a BDA session showing the Schematic Graphic Editor, the Building Browser and the Decision Desktop. The screen shows comparison of three alternative glazing and lighting control combinations, for a simple commercial building. The computations include 6 ECM and 6 DElight simulations, and 63 hourly energy simulations that show the relationship between window to wall ratio and energy requirement for window size optimization. Creating the building model from scratch and performing all daylighting, electric lighting and energy simulations took less than 20 minutes!

To draw a space, users first select from a list of space types and then proceed to drawing the space by drawing the walls that define it. The space type information is used by the BDA to further refine "smart" default values for non-geometric parameters, such as thermostat settings, recommended illumination levels, etc. At any point, BDA users can see the whole project data maintained by the BDA through the Building Browser, which is a user interface element that allows browsing and editing of the values of all objects and parameters in the project database (Figure 1).

2.1.1 The Building Browser

The Building Browser is composed of two side-by-side windows. The left window displays all of the objects in the BDA project database. The display is hierarchical, starting from the site object and unfolding into various hierarchies, e.g., building, story, space, walls, etc. When an object is selected in the left window, the right window displays all of the objects that are linked to the selected object, as well as all parameters that characterize the object. The right window contains columns that display values, units, and value sources for all objects and parameters.

Building object values, such as wall construction, glazing type, lighting fixture, etc., can be changed by selecting alternative options from the BDA object libraries, e.g., libraries of wall constructions, glazing materials, lighting fixtures, etc. Object parameters values, such as thermostat settings, work-plane height, etc., can be changed by direct user input.

To the left of each parameter in the Building Browser is an icon that shows either a computer, or a person. Computer icons indicate that the parameter has a default value, while person icons indicate values entered by users. When a user changes a default value, the computer icon is automatically changed to a person icon and the name of the user is automatically entered as the source of the value. In this way, the BDA allows multiple users to work on the same project, keeping track of updates.

To better support schematic design, BDA continuously maintains a space model linked to the wall objects, which are made up of wall segments. In this way, SGE users can move whole spaces around, while the BDA automatically computes interior and exterior wall segments for proper assignment of construction specifications.

Several "smart" options have been added to the behavior of the BDA building objects, which demonstrate the potential of object-oriented CAD. For example, if a space is moved to a new location that is adjacent to a window, the BDA will automatically remove the window; or if a space is moved to a new location overlapping another space, the BDA will not accept the new position and automatically put it back in its original position.

2.1.2 The Decision Desktop

Decision-making requires perception of value, which can only come through comparison of alternative options. To assist decision-making, the BDA supports the maintenance of multiple design alternatives, referred to as "solutions." When users select the New Solution option, the BDA duplicates the "current" design, creating a fork with two identical solutions, both of which can be changed as well as form the basis for more solutions.

The BDA user interface includes an element called Decision Desktop, which allows users to compare multiple alternative design solutions with respect to multiple descriptive and performance aspects. The Decision

Desktop is a matrix whose columns correspond to alternative design solutions and rows to parameters from BDA's building model (Figure 1).

New solutions are automatically entered as columns in the Decision Desktop. The parameters that occupy the rows of the Decision Desktop are selected by users in the Building Browser. Users control the display of parameters in the Decision Desktop through a checkbox to the left of each parameter in the Building Browser. If a selected parameter has a value, then the value is automatically entered in the Decision Desktop. Parameters that represent the output of simulation programs, such as DOE2.1E, DElight, etc., do not have initial values.

When a simulation output parameter is selected for display in the Decision Desktop, the BDA assigns the parameter to a Decision Desktop row without displaying a value. To display values for such parameters, BDA users request computations by clicking either at the header of the Decision Desktop column, or the Compute icon in BDA's main window. The BDA automatically prepares the input for the required simulations, activates the required simulation programs and then displays their output in graphical format in the Decision Desktop.

2.2 MODELING CAPABILITIES

The BDA building model can accommodate spaces of arbitrary geometric complexity. However, not all simulation tools can model spaces of arbitrary complexity. BDA is aware of the modeling capabilities of the simulation tools linked to it and automatically removes output parameters from objects that cannot be modeled by the currently available simulation tools.

The current version of the BDA software includes several simulation output parameters in BDA's building model. Some of them are computed through the activation of a single simulation tool, while others require the activation of more tools, using the output of one as input to another.

The DElight software is used to compute values for spatial and temporal daylighting illuminance and glare values. The ECM software is used to compute values for spatial electric lighting illuminance. ECM output is further manipulated to serve as input to the DOE-2.1E software, which is used to compute monthly and annual energy requirements by end use, e.g., heating, cooling, lighting, etc., and by energy source, i.e., electricity and gas.

3. Using the BDA in Architectural Design Studios

A greater presence of performance considerations in the minds of architects leads to better design. The current version of the BDA software addresses only daylighting, lighting and energy performance aspects. However, these

are enough to start introducing students to integrated building design, i.e., the consideration of more than spatial arrangement and aesthetic appeal from the initial, schematic phases of building design.

The objective of using the BDA in design studios is not to shift the emphasis of design considerations to daylighting or energy. The objective is to practice including them, i.e., to training the mind in considering as many performance aspects as possible while the hand is drawing the lines that define the building's form.

While the BDA software can certainly be used to model whole buildings it can also be used to quickly and easily compare alternative architectural considerations, such as the orientation of spaces and position and size of openings. Such comparisons can be done within a matter of minutes, starting from scratch (Figure 1).

4. Current status and plans for the future

The current version of the BDA software (version 3.0) is licensed free of charge and can be downloaded from http://gaia.lbl.gov/BDA. In the meantime, the BDA development efforts continue.

Current development efforts are focused at making the BDA software even easier and faster to use, e.g., supporting duplication of spaces and stories, adding performance parameters by further manipulating the output of the simulation programs to compute averages, minima, maxima, etc., as well as providing the option to view the graphical data in numerical, tabular format.

Current development efforts are also geared toward preparing the BDA software for use by the building industry. The next version of the BDA, planned for release in the fall of 2002, will include support for user-defined entries to all BDA object libraries. For windows the BDA will adopt the Window5 format (http://windows.lbl.gov/software/), which is used by most US window manufacturers for window-related data. Support for the Window 5 format, along with the currently supported IES format (IES 1993) for electric lighting fixtures, will allow BDA users to import manufacturers' data for actual windows and lighting fixtures.

Longer-term plans include the development of links to the Radiance lighting simulation and rendering software, which allows modeling of spaces of arbitrary geometric and photometric complexity. Finally we look forward to the opportunity of linking the BDA to one or more of the recent commercial CAD systems that use object-oriented representations for building components and systems.

We also plan to continue offering free of charge licenses for academic and research use of the BDA software, expecting that Universities and

Research Institutions will capitalize on the BDA software foundation to further extend and enhance it. Our current development efforts include streamlining of the main BDA code to make extension by other parties easier.

Acknowledgements

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References

Birdsall, B.E., Buhl, W.F., Ellington, K.L., Erdem, A.E. and Winkelmann F.C.: 1990, Overview of the DOE-2 building energy analysis program, version 2.1D. Lawrence Berkeley Laboratory Report LBL-19735, Rev. 1, Berkeley, CA.

IES: 1993, "Lighting Handbook: Reference and Application". 8th Edition, Illuminating Engineering Society of North America.

Klein, S. A., Duffie, J.A., and Beckman, W.A.: 1976, " TRNSYS - A Transient Simulation Program," ASHRAE Trans, 82, 623.

Helmut E. Feustel: 1998, COMIS — An International Multizone Air-Flow and Contaminant Transport Model, LBNL Report 42182

Hitchcock, R. J.: 1995, Advancing lighting and daylighting simulation: the transition from analysis to design aid tools. Proceedings of Building Simulation '95, International Building Performance Simulation Association.

Papamichael, K., Pal, V., Bourassa, N., Loffeld, J., and Capeluto, G.: 2000, An Expandable Software Model for Collaborative Decision Making during the Whole Building Life Cycle. Proceedings of ACADIA 2000 Conference, Washington D.C., October 19-22.

Trusty, W. B. and Meil, J. K.: 1997, 'ATHENA™: An LCA Decision Support Tool - Application, Results and Issues' - Proceedings: Second International Conference on Buildings and the Environment. Sponsored by CSTB and CIB TG8, Paris, France.

Ward, G. and Shakespeare, R.: 1998, Rendering with Radiance: The Art and Science of Lighting Visualization. Morgan Kaufman.

TANGIBLE INTERFACES TO EXPLAIN GAUDÍ'S USE OF RULED-SURFACE GEOMETRIES

Interactive Systems Design for Haptic, Non-Verbal Learning

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Abstract. This paper summarises the development of a machine-readable model series for explaining Gaudí's use of ruled surface geometry in the Sagrada Familia in Barcelona, Spain. The first part discusses the modeling methods underlying the columns of the cathedral and the techniques required to translate them into built structures. The second part discusses the design and development of a tangible machine-readable model to explain column-modeling methods interactively in educational contexts such as art exhibitions. It is designed to explain the principles underlying the column design by means of physical interaction without using mathematical terms or language.

1. Introduction

Architect Gaudí's extensive use of double curved surfaces in the design of the Sagrada Familia is unique in the field of architecture and an extraordinary example of a pragmatic, yet astonishingly elegant design approach. Representing an outstanding cultural and intellectual achievement, these aesthetics and the underlying geometric concepts are consequently of great public interest yet at the same time anything but easy to understand. The challenge is to explain complex geometry to people of various levels of spatial understanding, and to do this effectively, efficiently and across cultural boundaries such as language barriers. This research project aims at developing and providing new types of interactive art exhibits allowing users to explore advanced geometric modelling through manipulating a tangible computer interface using neither mathematical terms, symbols nor spoken or written language.

In place of conventional drawings, Gaudí communicated his design of the Sagrada Família through physical models, most of which were destroyed during the civil war in the 1930s and subsequently restored during the following decades. Their re-construction in form of digital 3D models plays a key role in the process of putting Gaudí's design into practice. Digital 3D models produced for the purposes of actually building the project, and already used collaterally (in this context) to develop explanatory material for the museum, mainly in form of animations and multimedia CD-ROMs. In order to enhance what has up until now been time-based material through physical real-time user interaction, novel types of interfaces and software had to be developed by the internationally collaborating team.

The product - a tangible interface presented in this paper - is a special purpose tangible computer interface feeding parameters changed in physical representations of two-dimensional geometries into the computer where they are translated into an interaction-driven video-projected output animation. It provides an intuitive and easy-to-understand learning tool explaining highly complex spatial operations based on Boolean geometry.

2. Double Helix Columns by Antoni Gaudí

Figure 1 illustrates the procedure by which Gaudí's 'rectangular' double helix column design is generated. Two rectangles are counter-rotated around the common centre point and simultaneously translated along the z-axis. Figure 2 [1] shows the resulting circumscribed volumes manifesting as a physical object suspended in time before and after a Boolean intersection as

[1] visualized by Prof. M.C. Burry and published in [6].

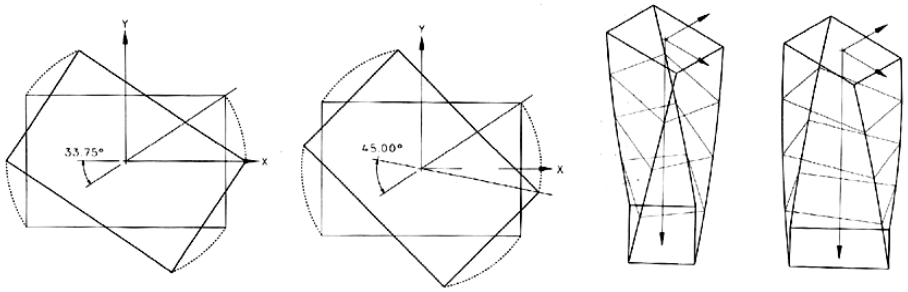


Figure 1: *'rectangular' column-modelling technique: Counter-rotation of two rectangles with a translation along the z-axis*

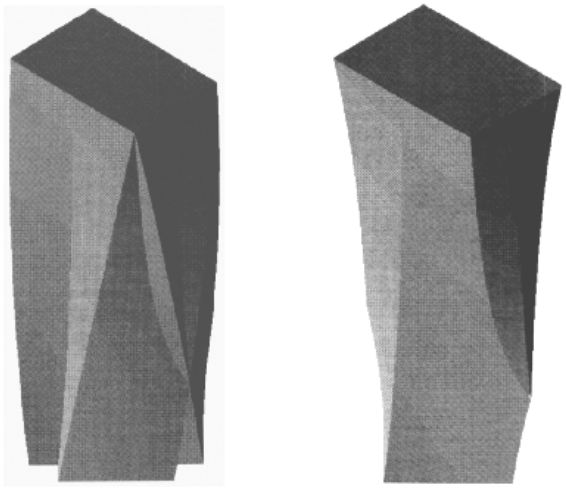


Figure 2: 'rectangular' column geometry before and after Boolean intersection[2]

found in one segment of the main columns of the Temple Sagrada Familia. In numerous variations Gaudí has made extensive use of the wealth of generative possibilities through the application of this principle. The complete columns in the Temple Sagrada Família are combinations of segments based on several of those variations. This generative process (figure 3) is reflected in the physical act of model making (at a scale of 1:10) on the building site of the Temple Sagrada Família.

Of all variations found in the temple design, there are a few relatively simple ones, which are based on rotations of only two profiles (other segments are based on multiple profiles). One of these segments is the rectangular column segment, shown on the right-hand side of figure 2. It is

[2] Taken from Gómez, J, Coll J, Melero J. C. and Burry, M.C: *La Sagrada Familia. De Gaudí a CAD*

found in the upper part of the main columns in the nave just below the point where the square sections – each based on two counter-rotated square profiles – branch out into the ceiling. Of those simple column segments, those with more significant rotation angles (12.5° and above) were selected for explanation by machine-readable models.

4. Machine Readable Model Design

> To display any object to its best advantage,
> be it a painting or a toothbrush,
> is always difficult: but displaying an idea is still more difficult,
> and the exhibition designer is often faced
> with both these problems at once.[3]
>
> [-- Richard Guyatt, 1950]

The three-dimensional volume of Gaudí's column (segment)s is circumscribed by two or more two-dimensional profiles.

As described above, the operation necessary to circumscribe Gaudí's columns is based on at least three (in case of two profiles) variables: The rotation of one profile, the corresponding counter-rotation of the second profile and the simultaneous translation of both profiles along the z-axis. Hence, initial ideas for the model design focused on the simultaneous input of all three variables (movements) similar to the prototyping setup (see figure 3) used to build 1:10 models on the building site in Barcelona. Real-time modeling, rendering of multiple variable input and variable perspective rendering have also been considered during early design stages but dismissed for the sake of simplicity for this first prototype in order to achieve a maximum of clarity during learning interaction. As all variables involved are functionally based on each other, the input of a single variable (rotation of one profile), a mechanical derivation of the second variable (counter-rotation of second profile) and a merely virtual representation of



Figure 3: Prototype modeling process on site in Barcelona

[3] Guyatt, R: *Models and Display Devices*. In Black, M 1950

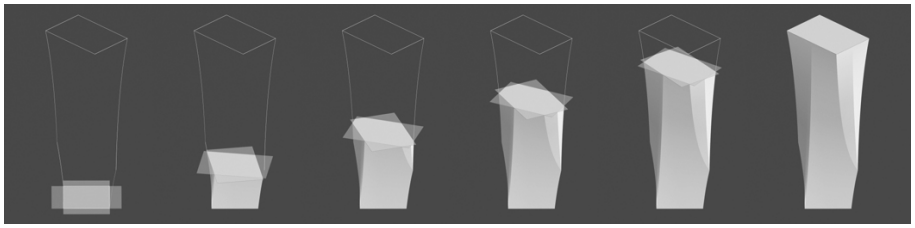


Figure 4: Visual output sequence

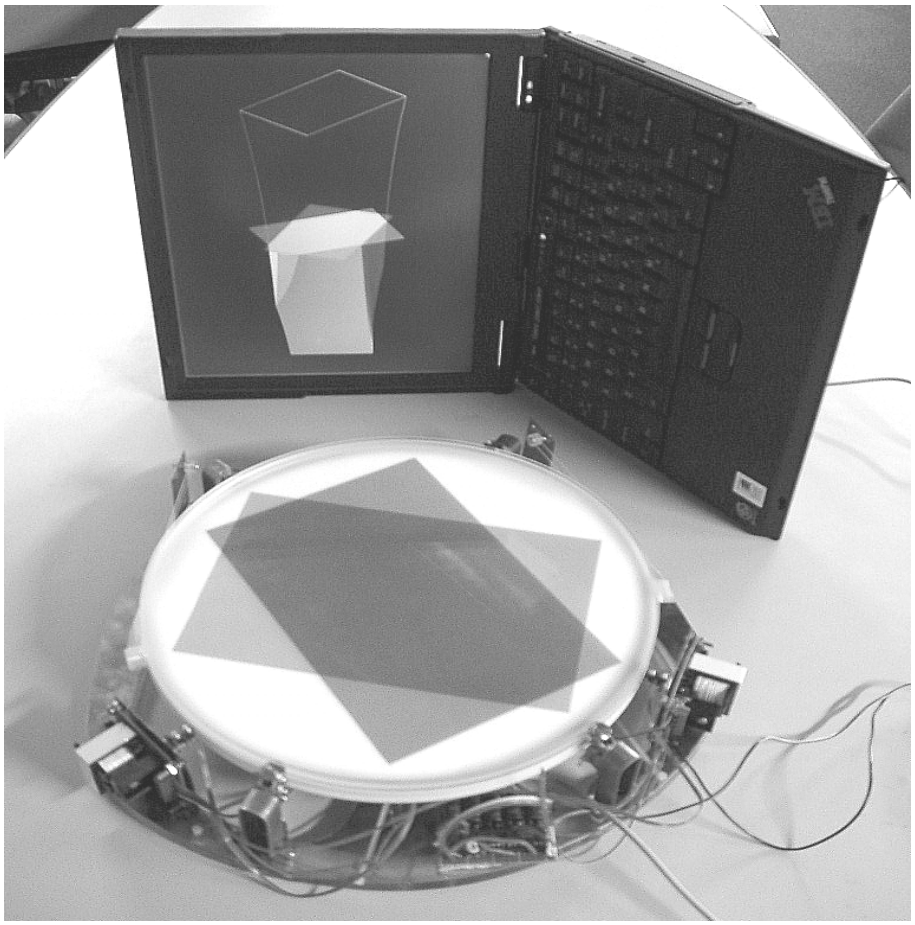


Figure 5: Tangible learning interface

the third variable (translation along z-axis) appear a more appropriate choice. It was thus possible to execute the interface model as a desktop turntable (see figure 5). Both two-dimensional profiles are represented by transparent color filters, which are also represented on the screen. In the overlapping area, both colours mix to a third colour which at any height

represents the according plane column section.According to users rotating one profile, the model automatically counter-rotates the second profile. A rotation sensor feeds this movement into a computer that interactively displays generated column segments (see sequence in figure 4). An interactive backlight for the coloured profiles and sensors for continuous auto-calibration have been installed.

Figure 5 shows the tangible model design (video screen is turned sideways to match the vertical orientation of the subject). Casings can be designed separately according to requirements in different exhibition scenarios. In contrast to previously produced mouse-controlled interaction interfaces with animation renderings, this setup allows the input of real-time data for the original rotation movement directly, involving haptic and visual input and feedback and thus allowing active, multi-sensual and user-driven learning.

As in previous haptic interface developments[4], the computer between input interface and output display, converting an analog input movement into an analog output visualization through an interim digital stage, is not visible to the user in its accustomed form with mouse and keyboard. It exclusively translates haptic user input into output, thus acting as a single-purpose machine whereas computers and their standard user interfaces are typically designed for multiple purposes. The advent of purpose-oriented interface design in architecture and learning requires interface and model designers to act as toolmakers[5] and to build complex computer-enhanced models for known purposes in defined scenarios.

5. Model Building: Conclusion

The design and implementation process of this special purpose computer interface represents typical leads we can expect from post-industrial and post-digital designing and building. Involving only a very limited number of products (as normally found in art or architecture) but high production accuracy and CNC manufacturing of CAD plans, it involves new industrial tools and methods such as laser cutting and CNC milling on one hand. On the other, it involves hands-on handicraft for those subtasks, which due to the small number of output products, cannot be supported by industrial tools (e.g. chassis bending and circuit board soldering work).

[4] see for example: Fischer, T., Ceccato C. and Frazer, J.H.: *Haptic Programming with Machine-Readable Models*. In: Burry, C.M. et al. (ed.): 2001

[5] Ceccato, Cristiano [1999]: Microgenesis. The Architect as Toolmaker: Computer-Based Generative Design Tools and Methods.

The context of readily available access to rapid prototyping and production engineering facilities has provided particular efficiency and played a key role in the design and implementation phases. Having these advanced CAD-CAM facilities available to the collaborators including advanced computerisation and high production speeds, the team has been provided with an ideal background for this type of one-off purpose-centered (post)digital interface development, thus supporting novel types of learning locally and abroad. This perhaps will become more the norm and less the exception in extending the role of computers in spatial design education.

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The authors acknowledge the contribution of the Sagrada Família technical office and Construction Committee in providing the purpose and motivation for this project. In particular, the Coordinating Architect and Director Sr Jordi Bonet is acknowledged for his insights especially with regard to the counter-rotating coloured profiles used in the haptic interface. The authors also acknowledge the considerable support from academic and research staff of the School of Design, especially the School of Design's Interactive Systems Design stream (led by Assistant Prof. Catherine Hu), the Design Research and Technology Centre and especially Cristiano Ceccato who continued contributing vital ideas to this project after changing his workplace. We also acknowledge the excellent support by Yasu Santo (Lingo programming) and SD's hands tool workshop staff, in particular Johnson Tam.

References

Black, M. (ed.): 1959, *Exhibition Design*. The Architectural Press, London, UK

Burry, M.C.: 1993, *The Expiatory Church of the Sagrada Familia*. Phadion, London, UK

Ceccato, C.: 1999: *Microgenesis. The Architect as Toolmaker*: Computer-Based Generative Design Tools and Methods. In: Soddu, C. (ed.): The Proceedings of the First International Generative Art Conference. Generative Design Lab at DiAP, Politecnico di Milano University

Fischer, T., Ceccato, C. and Frazer, J.H.: 2001, Haptic Programming with Machine-Readable Models. In: Burry, C.M. et al. (ed.): 2001, *The Proceedings of Mathematics and Design 2001 – The Third International Conference*. School of Architecture and Building, Deakin University, Geelong, Australia, pp. 158-165

Fischer, T., Herr, C.M. Herr and Ceccato C.: 2000, Towards Real Time Interaction Visualization in NED. In: Clayton, M.J.: 2000, ACADIA Conference Proceedings, Catholic University, Washington D.C

Frazer, H.J., Coates, P.S., Frazer, J.M.: 1983, 'Software and Hardware Approaches to Improving the Man-Machine Interface', *Computer Applications in Production and Engineering Conference*, Amsterdam, proceedings of First International IFIP Conference, North Holland 1983, pp. 1083-94.

Frazer, J.H.: 1995, *An Evolutionary Architecture*. Architectural Association, London, UK

Gómez, J., Coll J., Melero J.C. and Burry, C.M.: 1996: *La Sagrada Familia. De Gaudí a CAD*. Edicions UPC. Universitat Politècnica de Catalunya, Spain

Margarit J. and Buxade C.: 1969, *Calculo de Estructuras en Paraboloide Hiperbolico*. 1st edition. Publicationes del colegio official de architectos de cataluna y baleares, Spain

Velarde G. 1988, *Designing Exhibitions*. The Design Council, London, UK

The official Gaudí 2002 Barcelona / International Gaudí Year Web site: http://www.gaudi2002.bcn.es

Deakin University's Temple Sagrada Familia and Gaudí Web site: http://sagfam.deakin.edu.au

AN APPLICATION OF PHOTOGRAMMETRY MEASURING TECHNOLOGY TO PARAMETRIC MODELING OF KOREAN TRADITIONAL WOODEN STRUCTURE

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Abstract. To construct a 3D parametric model of Korean traditional wooden structure, the fundamental process is to obtain the dimensions of each building. An application of measuring high technology helps this process accomplished more efficiently. However PhotoModeler is a photogrammetric program to measure the dimension using photographs. The information derived from PhotoModeler is used to clarify the design rule inherent in a Korean traditional mansion type building - UnHyun Palace.

1. Introduction

The objective of this research is to propose a method of constructing a 3D parametric model of Korean traditional wooden structure. One of the fundamental processes of this research is to obtain the dimensions of each building by using PhotoModeler.

PhotoModeler is a photogrammetric program that extracts 3D models and dimensions from 2D photographs. Its official name is "Soft-copy analytic close-range convergent photogrammetric software system". If we have the photographs that include the parts we need to measure, PhotoModeler not only shows a 3D image of the part but also gives the dimensions. This research is to apply this program to measure the dimensions of Korean traditional building. The scope of this research is restricted within Korean traditional mansion type building.

Among many Korean traditional mansions, the UnHyun palace is the research case. This building is a representative building of late 19 C mansion type building and a good example to apply PhotoModeler. Even though we know the real measurements of this building, we picked this

building to compare the measurement obtained through the program with the real measurement.

2. Photomodeler for Measurement of Building Dimensions

2.1. TAKING PHOTOS

To use PhotoModeler, one or more photographs of a scene or an object are needed. Photographs are a key data for this program. It can be photos taken of the actual building or a demolished building. Since the structure of traditional Korean buildings is normally exposed, we can take photos in almost every aspect.

2.2. OPERATION IN PHOTOMODELER

The following operation shows how to measure dimensions of a purlin, a column top-tie and a column by using 4 photographs. These components are the principal components of traditional Korean mansion type structure.

The photographs are displayed on the screen. Afterwards, the operator should mark the outer shape of the component with lines or curves. PhotoModeler then combines the photographs and locates the marked features in three dimensions. The marks become accurate measured points, lines, curves, cylinders or polygons in a single unified 3D space. *Figure 1.* shows a 3D model of a purlin and a column obtained by using PhotoModeler.

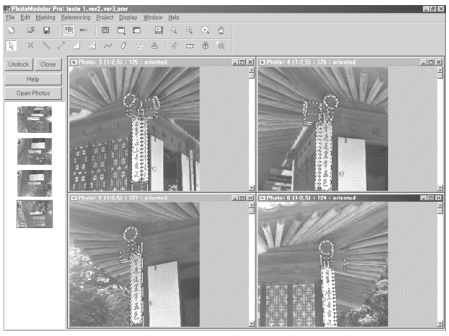


Figure 1. operation of Photomodeler

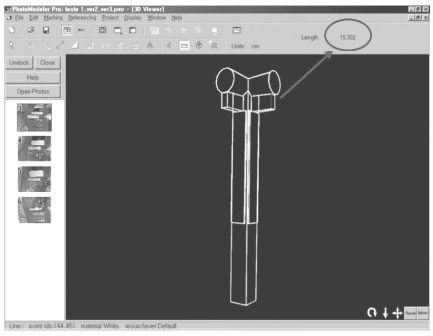


Figure 2. 3D modeling and measurement

A 3D model is a set of connected 3D points, edges, curves and cylinders which represent an object. Three dimensional points have coordinate values for each of the Cartesian axes(X, Y, and Z). PhotoModeler generates 3D

models for visualization and view studies. 3D model can be used to obtain the measurement of each of the component. If the operator knows at least one of the dimension, the tools of scale or control points uses this dimension to extract the real measurement. The dimension of foundation stone or the width of column that we can measure directly can be used as the constraint for scale.

2.3. ACCURACY OF PHOTOMODELER

How reliable is the result from PhotoModeler? No measurement technology can be perfect and all measurement involves performing approximations. PhotoModeler is no different.

First of all PhotoModeler depends heavily on the nature and quality of the photography used for measurement. The quality of photographs is very important to obtain accurate results. However the accuracy of a Measurement Project is dependent not only on the quality of photographs but also on other numerous factors: resolution and position of the camera and digitizer, precise marking, etc.

For example, a project done with the highest resolution Kodak DCS under reasonable user care, PhotoModeler has shown a relative accuracy in linear dimensions of around one in two thousand (1:2,000) for man made objects (with 95 % probability). With higher resolution medium format metric digital cameras shows an accuracy as high as 1: 10,0000. Lower resolution cameras and imprecise marking can reduce the accuracy to one in five hundred (1: 500) or even lower.

2.4. THE ROLE OF PHOTOGRAMMETRY IN ARCHITECTURE

Photomodeler is a modeling and measuring tool based on photogrammetry which is the science of extracting measurements from photographs. This high tech program can be used to measure the dimension of real buildings or buildings only existing in photographs. Therefore this photogrammetric program is useful also for restoration or documentation.

This research uses this photogrammetric program as a tool to clarify the design rule inherent in the tradition Korean architecture. More specifically, the following 2 types of ratio of this building are obtained from the dimension information collected by using PhotoModeler: layout ratio and component ratio.

3. 3D parametric model of Korean traditional wooden structure

3.1. PARAMETRIC RULE OF KOREAN TRADITIONAL WOODEN STRUCTURE

Korean traditional building is an assembly of wooden components. These wooden components are, by their shape similarities and common structural roles, classified into several categories each of which has it's own prototype. For example, circular column is a column prototype from which various different column instances are derived. The dimensions of a component are constrained by ratios. For example, a ratio exists between the diameter and the height of a column. One component may have several ratios among their different dimensions such as column diameter and height as well as mortise width and depth of column head.

Moreover, the assembly of wooden components is systematized like Lego. In other words, there exists a fixed rule in the connection between joining components, and a ratio of one component is related to that of another component in a sequential manner. Thus, the change of one component's dimension results in that of joining component's dimension. Reciprocally, the unknown dimension of a component may be derived from the given dimension of joining component when the interrelated dimensional ratios of joining components are known. The ratio between components also exist, for example, the width of column and the width of top-tie. As Korean traditional wooden structure is canonical in its form and assembly, dimensional ratios of wooden components are densely regulated.

Once 3D digital model of a Korean traditional wooden structure is constructed in terms of parametric modeling technique, we may determine component ratios and the dimensional change of one component may result in that of other components. The new development of photogrammetry measuring technology like PhotoModeler program makes it possible to collect the required information about component ratios from the photos of Korean traditional wooden structure.

However component ratios depends on house type as wells as building scale. As above-mentioned, column, column top-tie, purlin, and beam are the principal components in Korean traditional mansion type structure. The ratios of those principal components and interrelated connection between those ratios are the basic information, which has to be derived from the result of PhotoModeler program.

3.2. IMPORTING DIMENSIONS TO CAD SYSTEM

3.2.1. Component list and dimensions

All most dimensions are measured in Photomodeler. 3D model of UnHyun Palace is built by applying these dimensions to prototypes of components and applying location constraints to them. Its one bay is chosen to test this task sequence. The component list has a column, a top-tie, a purlin, a beam, a strut, a rafter. The detail attributes and imported dimension of these components are listed in Table 1.

TABLE 1.Ccompoenet List and Imported Dimensions

part	Shape Type	attribute	Dimension (unit : mm)
Column	in, out	widthTop	215
		widthBottom	230
		height	3120, 2670
Toptie	.	width	75
		depth	242
		length	2470
Purlin		radius	127.5
		length	2470
Beam	center, up, out	width	335, 176, 180
		depth	400, 394 ,300
		length	3696, 4325.5, 1546.6
Strut		width	896
		depth	95
		hight	970
Rafter	Short, long	radius	120
		length	2400, 3050

With the dimensions of parts, we need also the offset dimensions of columns and rafters, which are listed in table 2. Among them, the ColumnOffset :X is measured directly and it acts as standard dimension finding other dimensions according to ratio in Photomodeler.

TABLE 2. Offset Dimensions.

offset	direction	attribute	dimension
ColumnOffset	X	[0]-[1]	2470
	Y	[0]-[1]	1546.6
		[1]-[2]	3696
		[2]-[3]	1546.6
RafterOffset	X	.	240

3.2.2. Constraints

There exist two types of constraints in a building; location constraints and dimension constraints. We must decide where each components is located referring to the photographs. Location constraints can be different in each building.

TABLE 3. Location Constraints

Part	Location type	Location				
		spot	Linear			
			start	end	mid	direction
Column	in	On y[1], y[2]	.	.	.	.
	out	On y[0], y[3]	.	.	.	.
Strut	.	On Beam-center:center	.	.	.	.
Toptie	y[0] ~ [3]	.	On Column[n],	On Column [n+1]	.	x
	center	.	At 2/3 Strut[n]	At 2/3 Strut [n+1]	.	x
Purlin	y[0] ~ [3], center	.	On Toptie:start	On Toptie:end	.	x
Beam	out	.	On Column[n]-out	On Column[n+1]-in	.	y
	center	.	At Bean[n]-out:end	At Bean[n+1]-out:end	.	y
	up	.	On Column[n]-in	On Column[n+1]-in	.	y
rafter	short	.	On purlin-center	On purlin-y[1], On purlin-y[2]	.	y
	long	.	On purlin-y[1],y[2]	.	On purlin-y[0], On purlin-y[3]	y

* location type is same with shape type in case of column, beam and rafter
* [n]-[n+1] means nth bay of building plan.
* (-) type, (:) attribute

According to this table, we can define dimensional constraints.

Beam-center, up : length = ColumnOffset : Y (1)

Purlin : length = ColumnOffset : X (2)

Beam-out : length = (ColumnOffset : Y : [0]-[1]) + extrusion length of it (3)

3.2.3. 3D model of UnHyun Palace

Figure 3 shows the 3D model of UnHyun Palace obtained by the above mentioned process.

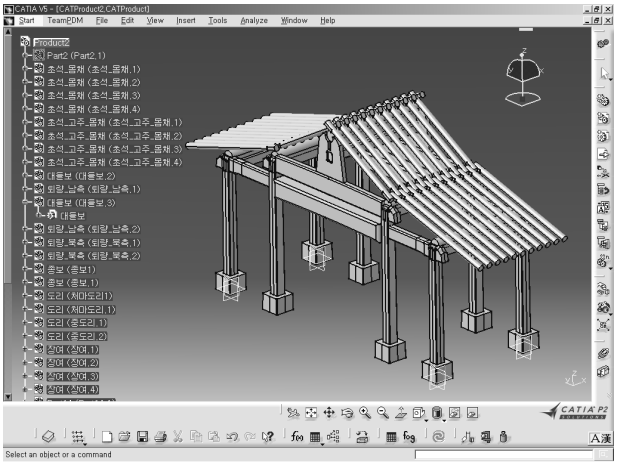


Figure 3. 3D model of UnHyun Palace in CATIA

3.2.4. Finding Dimensional Ratios

It can be classified two major types. First one is layout ratio of wooden structure: bay width of x direction vs. y direction, bay width of x direction vs. building height. Second is component ratio: Internal ratio is among dimensions of one component, and the external ratio between connected components. (Table 4)

TABLE 4. Result Values of Ratios

Ratio type		Param1	Param2	Ratio
Layout ratio		ColumnOffset : Y:[0]-[1]	ColumnOffset : X:[0]-[1]	0.626
		ColumnOffset : Y:[1]-[2]	ColumnOffset : X:[0]-[1]	1.496
		Purlin-center : location :z	ColumnOffset : X:[0]-[1]	1.672
		Column-out : height	Purlin-center : location :z	0.646
Component ratio	internal	Column-out : widthBottom	Column-out : height	0.086
		Column-out : widthTop	Column-out : widthBottom	0.93
		Toptie : width	Toptie : height	0.3
		Beam-center : width	Beam-center : depth	0.837
	external	Top-tie : width	Column-out : widthTop	0.349
		Purlin : radius	Top-tie : width	1.7
		Rafter : radius	Purlin : radius	0.94
		Beam-out : width	Column-out : widthTop	0.837
		Beam-center : width	Beam-out : width	1.86
		Beam-up : width	Beam-center : width	0.525

* purlin-center: location :z = The height of structure

The ratios in Table 4 are calculated by multiplication only. Although this

method is simple but it is clearer.

4. Conclusion

Photomodeler - a photogrammetric program - is used as a tool to measure the dimension of building. Application of this program to Korean traditional building – UnHyun Palace – gives the information for the 3D parametric modeling and make clarify the design rule inherent in the tradition Korean architecture like 2 types of ratios: ratios among the parts of a component, ratios between components and layout ratios. These ratios can be used to analyze the variation of each building components with the component prototypes.

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References

2000, PhotoModeler Pro4.0 User Manual, EOS Systems Inc. Vancouver

Ryo, Bok Mo,: 2000, Photogrammetry, Mun Un Dang, Seoul (Korean text)

Jang, Ki In: 1998, Wooden Structure, Bo Seung Gak (Korean text)

Kim, Marie (ed.): 2000, A Program Development of 3D Documentation System for the Korean Traditional Wooden Architecture, CAADRIA 2000 Conference, Sydney



3

COLLABORATIVE DESIGN, CREATIVE DESIGN & CASE REASONING

3

Collaborative Design, Creative Design & Case Reasoning

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INTERACTIVE STORYTELLING AND ITS ROLE IN THE DESIGN PROCESS

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Abstract. Projects of ever increasing complexity and size have incited the need for new and robust design methodologies and tools in an effort to manage complexity, lower costs, ascertain quality and reduce risk. Technology convergence through the growing availability of networked computers, rapid progress in Computer Aided Design (CAD) and information management have encouraged the undertaking of even more complex designs that demand high degrees of interaction, collaboration and the efficient sharing and dissemination of information. It is suggested that interactive storytelling and interactive design (Rafi and Karboulonis, 2001) techniques that use non-linear information mapping systems can be deployed to assist users as they navigate information that is structured to address localized needs as they arise. The design process is a collaborative effort that encompasses diverse knowledge disciplines and demands the management and utilization of available resources to satisfy the needs of a single or set of goals. It is thought that building industry specialists should work close together in an organised manner to solve design problems as they emerge and find alternatives when designs fall short. The design process involves the processing of dynamic and complex information, that can be anything from the amount of soil required to level lands - to the needs of specific lightings systems in operation theatres. Other important factors that affect the design process are related to costs and deadlines. This paper will demonstrate some of our early findings in several experiments to establish non-linear storytelling. It will conclude with a recommendation for a

plausible design of such a system based on experimental work that is currently being conducted and is reaching its final stages. The paper will lay the foundations of a possible path to implementation based on the concept of multi-path animation that is appropriate for structuring the design process as used in the building industry.

1. Introduction

The design process can be seen as a structured process within which actions or events (of processing information or production on site) will occur relevant to their location in the timeline. Certain events can only commence or conclude depending on other related events. It is proposed that the existing order enables the transformation of the design process to become non-linear and interactive with regard to the sharing of information and dissemination of knowledge. Interactive Storytelling media management specifies the mode or communication channel open for interaction and supply of information as required. The requested information can vary and depends on an individual's knowledge, experience and timeframe. Ultimately the processed information can become a new input to the system. Such a system would be designed to handle information that was stored in small, meaningful sections that in turn would assist navigation and the construction and authoring of large knowledge databases.

The multi-path structure can be organised with specific templates employing appropriate interfaces for the construction industry people. Such systems require people to key-in data and provide other textual information in addition to appropriate CAD files, video clips, audio data, Flash or Shockwave and VRML files for visualisation purposes. The data input should bind to the specific category of information and structure as defined by the software. The software engine will then structure the contents as requested or required by the user. Navigation within these information space requires certain "**problem-'choice of solution'-solution**" equations such as cascade correlation in Sarle's reports (2001). The input, which can be in the form of a problem statement, will be pushed forward for a specialist to analyse and define a possible solution. For them to understand the problem, they need to be given certain guidance by the specialist and be provided with just enough information to satisfy their query. This analytical environment is equivalent to multi-path storyline that is becoming the de-facto standard for web streaming animation content.

In multi-path storyline, a user is provided with a set of problems (objectives, goals, action-lists), that he or she needs to bring to a conclusion within a pre-defined set of parameters as laid down by the programmer or the software engine. The user starts the process by making a choice and

following a path that will take him or her to another scene where more choices have to be made. Making a choice is equivalent to taking a path through the story. If the user was to decide on a choice, the user could be taken to another set of problems to consider.

This suggests that the story might end differently for individual users but also that the same users may choose different paths next time they make a query since they are now more knowledgeable or because new information and paths have been added by specialists since their last visit. It is worth noting that while individual users may pursue the same goal, the paths taken are likely to be different and will depend on their current level of knowledge and experience. Therefore more experienced users will take shorter paths thus saving time where inexperienced users may benefit from choosing longer paths in the search of their goals. The fact that experienced and inexperienced users or users from different backgrounds are able to navigate the same information set at their own pace and speed is an attractive proposition.

If the metaphor is to be developed for the construction industry, we can see construction specialists navigating the same sets of information while adopting different approaches and reaching the same results and goals through shorter or longer paths. It is acknowledged that there will be a need for the periodic updating of the collected knowledge and this is a topic that requires further research.

2. The Experiments

The experiments content structure is developed in UML (Unified Modeling Language) style flowchart to maintain, define and track attributes, processes, results, events and choices (conditional statements). The flowchart allows many inputs in which each input is given an identification (ID) to be associated with certain category of users and specific individuals. The processor needs to understand the policy associated with a certain user. User queries to the database also require information concerning the user's identity, requirements, data ownership, system flow, last data usage, last location within the system flowchart and last process or action that the user has put effect on the system.

An event acts like a noun. It is dependent on a verb and a user action and a response to complete its function. An event can only function when a process is having an effect on it. An event can pass information to a carrier, an instance of itself, a process and to be stored and forwarded at a later time according to the timeline, availability and request. An instance can be an exact replication of the original copy. An instance can be a subset only containing minimum information, as the system feels adequate for the user

to continue navigating the system to achieve his preset goals. User behavioral patterns can be seen as the user manages an expected content structure which itself proposes the user's navigation style and preferences. The system needs to compare and conclude the path in which the user navigates to obtain the intended information or to complete certain tasks.

A universal pattern for most common navigation and data usage type needs to be identified early for the system to compare and use this information before assisting users. If the user navigates through the system in a manner familiar to the system, the system will establish the universal pattern as its reference. The system will use this to compare and clarify the effectiveness of the current user approach. This will be kept in a container that has the object's identifier code (e.g. a map of user walkthrough), media file header and instances.

3. The Events Structure

The main structure of the system represents a pipeline with different types of rings (of different insulation and materials) that carry information. The layering insulation acts as a filter to control information movement between rings and the ring itself (a container of specific media type, data type and functions). The information complexity, ownership hierarchy and length are the elements for defining their location. The core structure includes private data, a huge media file, complicated data types and low usage rates. Availability of objects in the information pipes to the user are decided by object ownership (unless if granted via administration presets or being defined by the object owner), task logical paths within the system and goal logical paths within the system. Logical paths are well suited for the user and the system's requirements. The system pre-programmed logical flow includes real-time processing and preset algorithm for the most common processes. The system is designed for the users to note a series of events for the effective use of interactive storytelling in a design process. This includes the followings.

1. System setting A will establish user history, previous setting/preferences, previous pattern and compare with current task.
2. System setting B will identify the user's previous location within the system, his path, last visited node, last usage of information, previous contents in his carrier and his achievements.
3. System setting C will check the possibilities for groups collaborative solutions depending on current users and terminal used.

4. System active configurations will prepare the system to create instances, and lay the most economical, popular and most used path by current user. The instances created will then be grouped and be made into families of information. If families were to have long-term relationships, the system will suggest a close and static connection with each other. Few high-bandwidth materials and resources will be made available and customised for long term users.

All grids will remain similar to any application. The data container can rotate, move and flex to gain new equilibrium and to function properly. Once the user states his responsibility, function within the system, task associated with him directly (and indirectly as seen by the system), event currently in progress, event of his interest and goals, the system will compute and propose a scheme. This will help the user to quickly find a way through the system and solve the problem or manage the right quantity and quality of information. The system will then broadcast the scheme throughout the network waiting for response and query. If the collective response for this broadcast is higher and relevant, the system will establish a common path for the user to start navigating and using the system (within the limitation as being defined for security and functionality purposes) (figure 1).

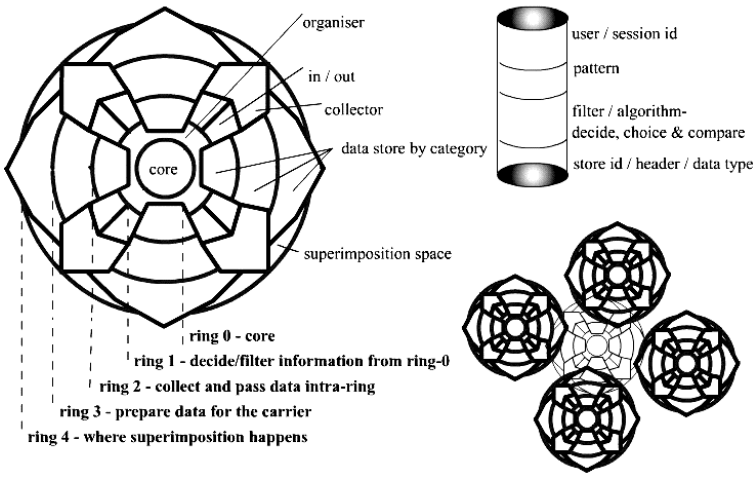


Figure 1. Shows the ring configuration.

A user is normally provided with appropriate bandwidth and limited sequences to ensure effective navigation in the system and view multimedia presentations and other resources that aid in making a decision. The user may also select the proper viewing/viewable ratio based on the level of complexity. Multimedia documents in the system are made available in the

form of static images, video clips, CAD drawings, vector drawings, 3-dimensional, VRML images, animations, colour schemes, building materials, spreadsheet documents, data only documents, audio files, sensor data and real-time web-cam footages. These documents are archived based on categories, functions and be made ready for sequential viewing via filters and transitions as users made selections and navigated through the system paths.

A user has the freedom to choose between various paths and choices that will eventually lead to a goal or a subset of another task/path. A path is a collection of objects (process, sub-process, task and other elements concerning finance, building materials, and other resources usages, management and physical entities.) which have been chosen by the system from various forms of information within and/or stored outside the system. Following through the path helps the user to compare options and simplify the 'problem-solving'. Selecting the simulation approach will guide within a few limited options to solve the current problem through forecast of output/result supposedly created by this decision.

An optimised path can be suggested by the system for the user's perusal. This optimisation can be based on the Ant algorithm. The logical flow or pattern is indeed a record of specific behaviour or a collection of behaviour. This behaviour constitutes primarily of choice-case problem solving for processes, sequences of tasks most suitable (economical aspect, practical aspect, safety aspect, client requirement, regulations control and environmental aspects) to start and finish processes.

The system architecture for this experiment includes a series of components i.e. a database (SQL), processing software (PHP), query, retrieval and display applications (javascript-enabled browser/Macromedia Flash) and a customisation application. It comprises of a data locator and container. In the data locator the function is activated when the system starts broadcasting the user settings. The data locator will conclude upon the system's response and query. The data locator will leave a trail (pheromone trail-based on ant system) for the system to use as a guide for later use. The data container is a single unit cell that contains the basic data (of specific to its container's function and status) and relative data header (that define connection, linkage type and path, to other containers). Data containers are usually being grouped together to form a small family of information. The next neighbouring family can contain mostly relative and instances of farther apart containers. This family relationship can change upon requirement, request and user specifications and goals. This will operate based on the following rules:

The system will identify and compare with the most common pattern to the problem currently introduced by the user. If it fits, the signal playbacks the scenario. Alternatively, the user can track and analyse the preferences

and actual problem settings. Certain problems can involve emotional response, habitual practice and other sensual data not included in the system (figure 2).

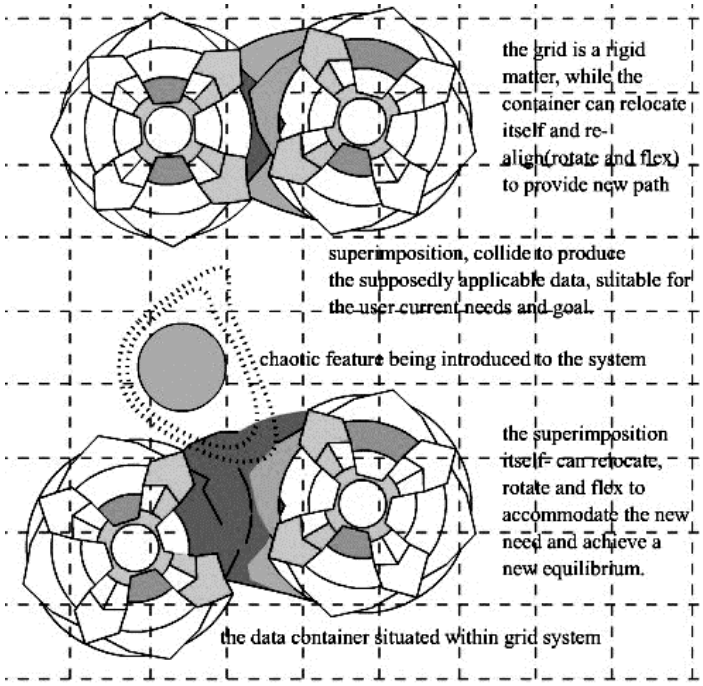


Figure 2. Show the possibilities of pattern.

4. Conclusion

This paper has outlined the mechanics that enable an intelligent and self-learning system capable of providing solutions to users' queries according to specific rules and structure stored within the system, as well as through typical methods most commonly used by users practiced within the scope of the system. The requested information can vary and depends on an individual's knowledge, experience and timeframe allowing users to traverse different paths that best suit their profiles.

To aid the design of the system this text has presented the design process as a structured process within which actions or events will occur relevant to their location in the timeline. It has been shown that a strong and well-informed structure enables the controlled enlargement of the underlying databases as well as the ability of the system to automatically track and suggests the appropriate navigation.

References

Rafi, A. Karboulonis, P.: 2001, The Re-Convergence of Art and Science: A Vehicle for Creativity. In the Proceedings of the 5th Conference on Computer-Aided Architectural Design Research in Asia (CAADRIA).

Sarle's, W.: 2001 ftp://ftp.sas.com/pub/neural/FAQ2.html#questions

A CONTEXTMANAGER FOR MULTIMEDIA PRESENTATION IN INTELLIGENT CORNERS

A Human-Centric Interaction Approach

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Abstract. This paper presents an *Intelligent Corner* project using a *ContextManager* for coupling human action with physical material and digital information. This paper focuses on multi-modal interaction between human and tangible media in a ubiquitous computing environment. A *ContextManager* is deployed for managing human-centric interaction and mediating computational tasks in an Intelligent Corner. This experimental study integrates tangible user interface and ubiquitous computing for users to experience multimedia presentation in a rich and comprehensive environment.

1. Introduction

Multimedia technologies have been intensively used by designers to present digital design work. In presentations, designers demonstrate design work via the friendliest tools (i.e. *Gestures, Voices, and Annotations*) to express concepts and ideas. There may be physical models, drawings, and interactive movie clips on PDA, PC monitors, and wall-sized screens supporting different ways of digital presentation. Multimedia has become an inevitable way for interacting with human visually and acoustically. But using multimedia technologies, the integration among human, computational devices and digital information has become a difficult task since the interaction between them is getting more complex. A challenge before us is to develop a human-centric interactive environment that integrates ubiquitous multimedia and heterogeneous computational devices for a rich and comprehensive presentation.

Ubiquitous computing has provided an opportunity to develop a pervasive, yet invisible, intelligent environment for multimedia presentation. In this paper,

we propose an *Intelligent Corner* where designers can interact with digital information via ubiquitous yet manipulable computational devices. In Intelligent Corner, we purpose a ContextManager to manage interaction between both physical and digital representation in context. *Intelligent Environments* (IEs) have been widely discussed making the complexities of executing low-level commands embedded in human-centric computational environments (Coen, 1998) (Brooks et al., 1999) (Dertouzos, 2001). Multi-Agent Systems are developed to meet the computational needs for distributed computing in intelligent environments (Coen et al.,1999). Context-sensing network draws the special attentions on sensor technology and distributed computing for context-aware applications (Dey, 1999). Tools for capturing voices and annotations in design processes allow synchronized playback (Gross, 2001). Tangible user interfaces (Ullmer and Ishii, 2001) and multi-modal systems (Coen, 2000) integrate the cross-modal interaction that is *human-centric* for the direct interaction with physical material. In this paper, we explore human-centric interaction in a ubiquitous computing environment for users to experience multimedia presentation. The objective of ContextManager is to *manage interaction events between human, artifacts, and multimedia*.

2. A Conceptual Framework

In this paper, we take a human-centric approach to developing an Intelligent Corner, allowing people to use gestures, voices, annotations and other physical actions to interact with digital information. To characterize such an Intelligent Corner, we propose a conceptual framework for better understanding of technological engaged practices in multimedia presentation. In *figure 1*, an Intelligent Corner is composed of three components:

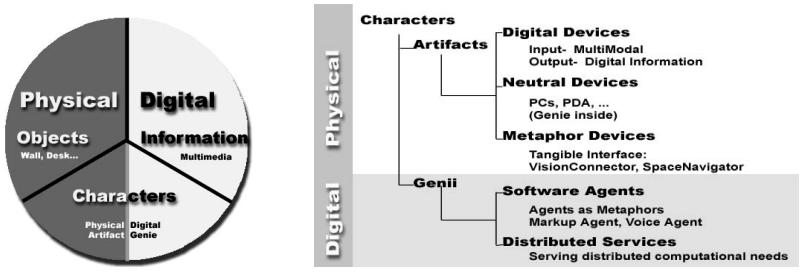


Figure 1. Characteristics of an Intelligent Corner

1. *Physical objects* Physical objects exist in a static form in the physical environment (i.e. wall, desk, stone…)
2. *Digital information* Digital information is as multimedia for digital design presentation through visual displays, graphical representation, and

video/audio…etc.

3. *Characters* There are two fundamental levels of Characters: *artifacts* in the physical world and *genii* in the digital world. Artifacts can be classified into three categories: digital devices, neutral devices, and metaphor devices. *Digital devices* are connected to PCs for multimodal inputs and multimedia outputs. *Neutral devices* (i.e. PCs, PDA) are driven functionality dynamically due to the computational tasks but do nothing if no tasks given. *Metaphor devices* are visual metaphors (Dourish, 2001) interacting with human actions directly. *Software agents* manage the input data and commands internally (i.e. Markup Agent for annotations and Voice Agent for speech recognition). *Distributed services* are software functions that serve the computational needs from remote servers.

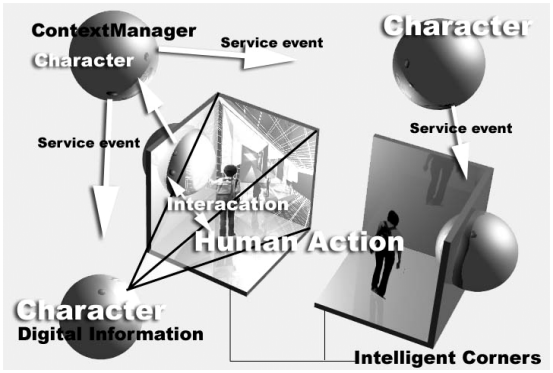


Figure 2. Concept of an Intelligent Corner

In Intelligent Corners, human acts on the physical part of a Character, as illustrated in *figure 2*. These kinds of actions are *explicit* interaction events that could be imposed by physical actions (i.e. touching the screen, moving or rotating a joystick) or multi-modal actions (i.e. talking with microphone, walking around, and sitting on the table). An *external* interaction event triggers computational services to an event network between Characters. The computational service events are *implicit* (i.e. execute low-level commands or operations) that occur *internally* (i.e. open the projector, display an image file, and play music). An interaction event will result in an event chain-reaction in background in order to make better user experiences in Intelligent Corners.

3. Intelligent Corner

Intelligent Corners is to explore the human-centric interactions for better user experiences in multimedia presentation. Some experimental studies are taken in a human-centric approach. First, physical models and drawings made into

tangible user interfaces are the most familiar way for designers to interact. Secondly, characteristic of each Character has been created in a scenario for presentation. Thirdly, an integrated design of physical and virtual spaces is set up as Intelligent Corner prototype.

3.1 TANGIBLE USER INTERFACE

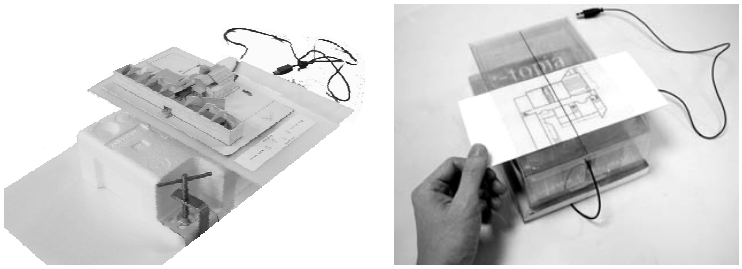


Figure 3. Physical Models and Drawings are used as metaphors for designers

Tangible user interfaces employ physical artifacts both as representations and controls for computation media (Ullmer and Ishii, 2001). The direct manipulation interface is to explicitly represent the object that users will deal with and to allow users to operate on these objects directly (Dourish, 2001). Physical models and drawings are used as tangible interfaces for designers to interact with digital information in a comprehensive way. As shown in *figure 3(Left),* we created a device that consists of physical model and a joystick used for a concept that serves *what you move (the model physically) is what you saw (in the monitor digitally)*. In *figure 3(Right)*, there's a drawing installed on an optical mouse that serves the concept of *cutting sections (on the physical drawing) and seeing spaces (in the monitor)*. We generate 3D models and interactive mechanisms coupling the physical artifacts with multimedia. These kinds of tangible user interfaces allow users to experience directly in a metaphorical way.

3.2 SETTING UP CHARACTERS

Physical models, drawings and interactive movie clips on PDA, PC Monitor, and the wall-size screen support different ways of presentation. A scenario has been developed for multimedia presentation to give specific characteristic to each Character. As illustrated in *figure 4*, tangible interfaces are connected to 3D models for VR simulation and navigation. The interactive multimedia movies meet the needs for designers to present digital design work.



Figure 4. Tangible interface as metaphors leads to a rich and comprehensive presentation

3.3 INTEGRATED DESIGN OF PHYSICAL AND VIRTUAL SPACES

A user experiences direct interaction with the qualities of action-*Direct Manipulation* and the subjective response-*Direct Engagement* (Laurel, 1993). Since multimedia has become an inevitable way for us to interact visually and acoustically. Some spatial settings in Intelligent Corner are set for multimedia presentations. As illustrated in *Figure 5*, direct interaction is promoted to occur on physical artifacts through direct manipulation on metaphor devices. Software agents will perform tasks for multimedia presentation to switch on/off visual displays or sound effects on digital devices. Through the manipulation on physical objects we can interact with digital information via ubiquitous computational devices around us.



Figure 5. Interacting with digital information through direct manipulation.

4. A ContextManager

In Intelligent Corners, pervasive computational devices (i.e. Notebook PC, Projector, Tablet PC, PDA…etc.) are deployed and integrated into an event network. Through the direct manipulation on devices physically, we purpose that the other devices will generate peripheral digital information in return. When interactions among system components are getting complex, resource management has become an essential part (Coen, 1999). We propose a ContextManager as one of the Characters to manage the event network in background serving two purposes. First, ContextManager captures events that occurred *externally* by multi-modal inputs or physical actions on tangible user interfaces. Secondly, ContextManager manages service events *internally* to execute low-level commands or operations.

4.1 MULTI-MODAL INTERACTION

In Intelligent Corner, designers demonstrate digital design work via *gestures, voices, and annotations* to evoke each software agent to perform tasks. The ContextManager is taking control of a multi-agent system that is responsible for multi-modal input, including:

1. Voice Agent for recognizing keywords input and executing *Play* commands such as launch a Media file. Voice inputs via Microphone and video outputs via AV projector.
2. Markup Agent for annotating on a transparent window overlapping drawings via electronic pen on TouchPad.
3. Tracking Agent for recognizing gestures and executing *View* commands such as Zoom-In, Zoom-Out. Motion tracking inputs via WebCams.
4. Recording Agent for recording video, audio via Digital Video camera.

4.2 SOCIAL SETTINGS IN CONTEXT

During the presentation, the ContextManager captures how the digital design project has been presented according to human actions on artifacts and multi-modal inputs. Then, presentation will be partitioned and re-activated if interaction events occurred.

We use ContextManager to capture events and *re-cast* them *in sequence* to make user experience the sequential events occurred before. This pre-definition addresses that some social logics may not be always *implicit* in context. We can pre-define social rules in the event network.

In general, the ContextManager will mark human actions events in background and also be responsible for orchestrating service events to enhance multimedia presentation, classifying related multimodal interaction, and re-organizing service events due to information embedded.

4.4 THE IMPLEMENTATION

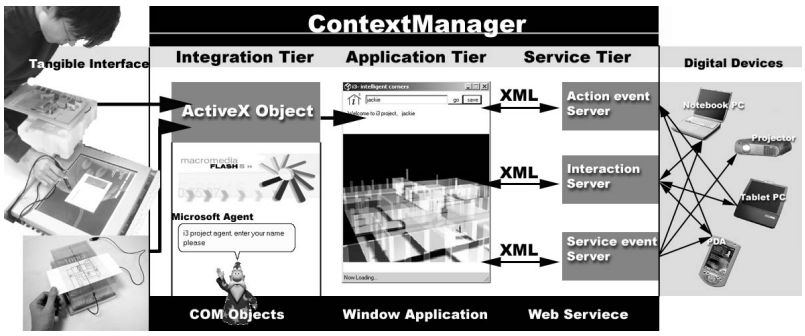


Figure 6. ContextManager deals with inputs from tangible user interface and outputs to digital devices.

As illustrated in *figure 6*, the ContextManager deals with the multimodal inputs from tangible user interfaces and multimedia outputs to digital devices. Internally, the ContextManager consists of three tiers:

1. *Integration tier* This tier integrates the multimodal inputs and digital representations. Microsoft Agent is used for speech recognition input and text-to-speech output. Flash movies are used for multimedia integration (i.e. 3D models, interactive movie clips, graphical display and music). We encapsulate them into ActiveX Objects as COM components embedded in the Window applications.
2. *Application tier* This tier that performs the most low-level commands and operations to handle the data from ActiveX Objects and store it into a remote database. This tie generates and transfers XML to remote server, and receives events as XML into database.
3. *Service tier* This tier manages the event network (i.e. action events, interaction events and service events) to each specific Digital devices using XML as communication protocol in a client-server relationship.

ContextManager captures and manages the interaction events in XML. Multimedia expressions are represented as XML tags with extensibility, and structural representation (i.e. <Rotate_X>3D Model </Rotate_X>). Each character deals with XML I/O as service events. ContextManager is implemented by C# which is deployed and performing computational tasks in a server.

5. Discussion/Future Work

An Intelligent Corner is attempted to provide a new way to present digital design work by coupling tangible user interfaces in a ubiquitous computational environment. We take a human-centric approach to managing interactions

between human, artifacts, and multimedia. A *ContextManager* is deployed for monitoring human action on physical artifacts and for casting computational service events in background. Through the direct manipulation in touch and direct engagement in context, users can experience digital design directly in a comprehensive way. We also found that some social activities occurred that is related to the settings we defined in ContextManager. In the Intelligent Corner prototype, we conclude that a ContextManager is an efficient way to integrate and facilitate multi-modal interaction and multimedia presentation in a human-centric computational environment. The future work of Intelligent Corner project is to make it distributed and connected between architectural spaces.

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References

Brooks, R.(ed.) :1999, The Intelligent Room Project, Proceedings of the Second International Cognitive Technology Conference (CT'97), Aizu, Japan

Coen, M., B. Phillips, N. Warshawsky, L. Weisman, S. Peters, and P. Finin :1999, Meeting the Computational Needs of Intelligent Environments: The Metaglue System., In Proceedings of MANSE'99, Dublin, Ireland

Coen, M. :1998, Design Principles for Intelligent Environments, Proceedings of AAAI'98.

Dertouzos, M.L. :2001, *The Unfinished Revolution: Human-centered computers and what they can do for us*, HarperCollins Publishers, Inc., USA

Dourish, P. :2001, *Where the Action is: The Foundations of Embodied Interaction*, MIT Press.

Dey, A.K., D. Salber, and G. D. Abowd., :1999, A Context-based Infrastructure for Smart Environments, In the *Proceedings of the 1st International Workshop on Managing Interactions in Smart Environments (MANSE '99)*, Dublin, Ireland, December 13-14, 1999. pp. 114-128. (http://www.cs.tcd.ie/MANSE99/)

Gross, M. D., E. Y-L. Do, and B. R. Johnson :2001, The Design Amanuensis: An Instrument for Multimodal Design Capture and Playback, Proceedings of CAADFutures 2001, Eindhoven, Netherlands, pp. 1-13.

Laurel, B. :1993, *Computer as Theatre*, Addison-Wesley Publishing Company, Inc.

Mitchell, W.J.:1999, *e-Topia*, MIT Press.

Ullmer, B. and H. Ishii,: 2001, Emerging Frameworks for Tangible User Interfaces, *Human-Computer Interaction in the New Millennium*, Addison-Wesley, August 2001, pp. 579-601.

Research of *Intelligent Corners* can be found at http://www.arch.ncku.edu.tw/ialab

WHAT DESIGNERS SEE FROM A CASE? A COGNITIVE APPROACH

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Abstract. In the behavior of human cognition, Schank, a cognitive researcher, claims that human frequently rely on past experience to solve new problems. The information and knowledge of well-trained designers was obtained from fundamental training courses in schools, from everyday experience, and importantly from several design cases. Acquiring knowledge by seeing cases is the most important activity in the design process. But, there are no related works from cognitive view to discuss what and how designers see from instances. Thus, this paper attempts to investigate what designers can see as some meaningful elements from instances, what relationships are among elements and knowledge which retrieved from designers' long-term memory, and how new obtained knowledge influences the design outcomes.

1. Introduction

Design is one kind of ill-structured problem, in which some kinds of designing information and knowledge can only be applied to a specific design issue. The information and knowledge of well-trained designers was obtained from fundamental training courses in school, from everyday experiences, and, importantly, from many design instances (Purcell and Gero, 1991). In terms of human cognition, Schank (1986), a cognitive researcher, also claims that human frequently rely on past experiences to solve new problems.

Design can be regarded as a "seeing-moving-seeing" process, in which designers dialogize with all the design information which can be identified by designers (Schön and Wiggins, 1992). They will not only see sketches

which they generated continuously, but consult some related instances. As seeing design instances, designers will translate some parts, or elements, of cases into their design knowledge and, then, apply both new and original knowledge in new design projects. Moreover, in Christiaans and Andel's (1993) paper, they propose that within the learning process students acquire much knowledge on a operational or procedural level by being exposed to a large number of examples of solutions.

In order to realize the decomposing process of the instances, this paper reviews some cognitive approaches about how human see a figure or a case. In visual cognitive research, Reed (1974) addresses that, while people saw a figure, they would decompose it into small, significant elements. Moreover, Kosslyn and his associates (1983) pointed out that the decomposition of these elements depended on the shapes which were meaningful to human and stored in his/her long-term memory (LTM). They also address that an image could be stored by separated elements with a significant schema. But the complicated shapes, which consisted of different sub-elements, will consume more time to store them. Then, human will use these sub-elements to recognize familiar elements, which were embodied in other shapes.

2. Problem and Objective

Acquiring knowledge by seeing cases is the most important activity in the design process. But, there are no related works from cognitive view to discuss what and how designers see from cases. Therefore, this paper attempts to investigate what designers can see as some meaningful elements from instances, what relationships are among elements and knowledge which retrieved from designers' LTM, and how new obtained knowledge influences the design outcomes.

3. Cognitive Experiment

The cognitive experiment of this study is included two major parts: a analyzing and associating section, and a designing section. In the first section, the subjects were asked to analyze the instances to acquire design knowledge, and associate to the knowledge they have stored in LTM. Second, in the designing section, the subjects should develop some ideas from the instances and their expertise of design by sketching on papers. In order to explore the processes of how designers obtain design knowledge and link original knowledge, the subjects have to draw and/or think-aloud

during the experiment. And whole processes are recorded by digital camera for protocol analysis.

3.1. DESIGN TASKS AND SUBJECTS

The purpose of this paper is to realize how the designers learn design knowledge from instances. To achieve this aim, the selection of design task should ensure that designers are not familiar with and have no experience about design topic. Thus, the knowledge of designing this topic will be acquired by designers from these instances provided by this study. The design task, which subjects analyze and design from instances, is an industrial product--a juicer, which is easier to deal with its function and form than any architecture design project.

Because of the different designing strategies among designers, this study invites two expert designers to be subjects of the cognitive experiment. The first subject, A, who now engages in designing the form of transportations, has 11 years for designing industrial products, while the other, B, has 13 years experience of related product design. Although neither subject A nor B has experiences for designing the design task, a juicer, they have had plentiful design knowledge which was accumulated by designers from past designing experiences and observations. It is impossible to examine all of their design knowledge in this paper. Therefore, this study only investigates the knowledge structure related to the design topic.

The selection of design instances is showed in figure 1. This study provides three instances for designers to analyze and learn. The first instance (figure 1a) is a normal juicer, which is without designing, but easy to use in functions. The second one (figure 1b) which designed by Alessi is to equally emphasize its form and function. A classical juicer (figure 1c), the last one, is designed by a famous France designer, Philippe Starck. His famed work integrated art and function.

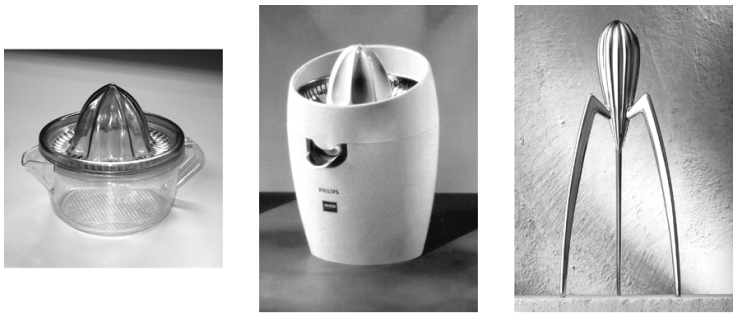


Figure 1. The selection of design instances.

3.2. THE STEPS OF EXPERIMENT

The experiment is processed by following sequences: warm up, analyzing and associating task, and designing task. All procedures will be taped by a digital camera for protocol analysis.

Warming up: the warm-up task was used to accustom the subject to the methodology of think aloud while designing and the process of formal task. The topic of this warm-up task is a tea pot which designed by Philippe Starck. The section of warm-up is to ensure that the subject is suitable for protocol experiment.

Analyzing and associating task: the objective of this section is to reveal how the designer analyze cases and associate the knowledge, either expertise of design or common knowledge, which have been stored in the LTM. The instances will be sequentially viewed and analyzed one by one (figure 1a to 1c) by each subject. For each instance, the subject has to analyze it in terms of either forms or functions, respectively, or both of them, and then, associate the related knowledge. Finally, after analyzing and associating each instance, they develop an idea which derived from the instance. In this task, the subjects are asked to articulate and sketch what they saw and thought at the same time.

Designing task: After the analyzing and associating task, the two subjects should gain some design knowledge about a juicer from these three instances. In the designing task, they are requested to develop an idea to figure out how they applied knowledge from either instances or the original one which retrieved from their LTM.

4. The Coding System

The methodology of protocol analysis has been extensively used to scrutinize the design behavior (Eastman, 1970; Akin, 1978, Akin and Lin, 1995; Gero and Neill,1998). After Akin's (1978) study, there were numerous researchers to dedicate to methodology of protocol analysis in terms of the different scheme of coding system. The coding system is the most vital part of protocol analysis because different coding systems, which inspected the design processes from different point of view, will yield diverse results.

In Akin and Lin's study (1995), they advance a coding scheme to investigate the activities that occurred during the process of design. Based on coding the activities of designers, they propose that these external activities could be relevant to the internal behavior of thinking. On the contrary, in terms of analyzing the problem domain and design strategy, Gero and Neill (1998) claim that when designers were solving design problems, they would analyze them in both macro and micro point of view. This point has

influenced the understanding of design action during design process. Moreover, they also advance that coding by level of abstract of what designers focus on could find that the attentions of designers may shift from macro to micro view or from micro to macro view.

Therefore, the methodological researches of protocol analysis will present a variety of coding scheme. Because of the particular purposes of coding systems, there are a lot of limitations of each coding scheme, but I will not discuss the discrepancy among them. However, the coding scheme that encoded in terms of sketches and design knowledge was not presented yet. In order to interpret how designers consult design instances and associate with related knowledge, the paper proposes a preliminarily coding scheme, which could encode the sketches generated by designers and the knowledge they applied in the process of developing ideas.

In the cognitive experiment, the results by observing the design behavior can be divided into two main categories: designing actions and utilizing sketches and related knowledge. Accordingly, the coding system of designing actions will be based on examining-drawing-thinking (E-D-T) (Akin and Lin, 1995). Nevertheless, in order to record the action of viewing instances by designers, the coding system of this paper will extract the behavior of consulting instances from Akin and Lin's coding scheme, examining (E). The consulting (C) will identify that the design knowledge was from instances. In addition, there are two new items of coding system: gesturing and associating. The gesturing (G) code intends that the gesturing action could be used to simulate the using of real products, while the associating (A) code shows the sources where was the design knowledge from: from instances (Ai), from expertise of design (Ae), and from common knowledge (Ac) (table 1).

TABLE 1. The coding system of designing actions.

E	examining	Examining the sketches which he has drawn
D	drawing	Drawing on papers which could be taped in the digital camera
T	thinking	Without examining or drawing
C	consulting	Consulting the instance provided in this study.
G	gesturing	Using hands to simulate some actions.
A	associating	where was the design knowledge from
	Ai	from instance
	Ae	from expertise of design
	Ac	from common knowledge

On the other hand, the coding system of utilizing sketches and related

knowledge follows the main idea from level of abstract (Gero and Neill, 1998). But, in the design process, designers will draw or associate elements which composed the product by sketching or linking to related knowledge. Each element also has its own properties for designing and associating. Thus, the coding system will aim at the elements of product and their properties to encode, precisely, each knowledge which be applied in the design process by designers (table 2).

TABLE 2. The coding system of utilizing sketching and related knowledge.

Elements of a juicer		
a	whole	The whole body of product.
b	Head	Where the orange was extracted by pressing.
c	Filter	Filtering the juice.
d	container	Where the juice flowed in.
e	Handle	Hold the juicer to pour into cups.
f	Outlet	Pour out the juice.
g	Feet	Support of a juicer.
Properties of elements		
	Pm	Material
	Pa	Axis
	Pu	Use
	Pf	Function
	Ps	Shape

Therefore, I represent level of abstract by using the coding system of utilizing sketching and related knowledge(table 3).

TABLE 3. The level of abstract by using the coding system of utilizing sketching and related knowledge.

level of abstract		sketching and related knowledge codes
0	System	a-Ps
1	Interactions	b & c
2	Sub-system	b, c, d
3	Details	b- Pa, c- Pm

5. Results and Discussions

The consequence of the cognitive experiment shows that designer will consult instances by analyzing and learning their original concepts, and, then, break them out to avoid the similarities between new ideas and

instances. In the case of subject B, during his experiment of instance b (figure 1b) designed by Alessi, he has obtained the axis of non-vertical and horizontal(figure 2a). In the further designing action, he first draw the axis of new idea on the other side of vertical (figure 2b). In another case, subject A has learned a concept, gracefulness, from instance c (figure 1c). Then, he interprets this concept by his past expertise of design to generate an idea which is fulfill the concept of gracefulness. In addition, the major function of a juicer is from the head of this product. Because the function of extracting juice by pressing is well-developed by instances, designers will prefer not to re-design it.

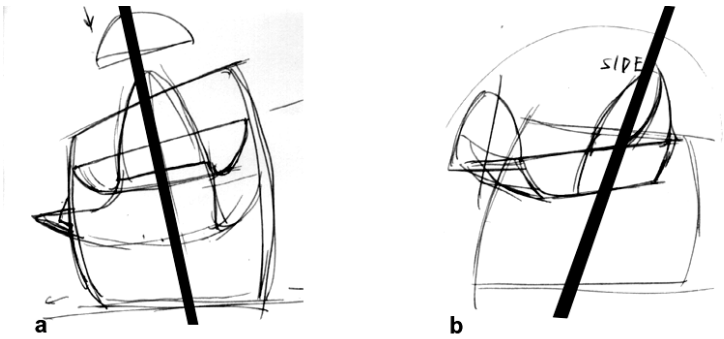


Figure 2. The axis transition from instance (a) to new idea(b).

In the designing process, designers will draw either front or perspective view to deal with the first part of idea. When they encounter the difficulty of describing concepts, they will draw another view with more details to indicate their ideas. In addition, the paper also find that the nomination of each element is not meaningful for designers because they use the words, "this" and "that", to point what they see, consult, and, even, think when they were developing ideas.

This paper does not present entire coding results, but proposes some phenomena which found in the cognitive experiment. The further study will focus on completeness of coding system to encode the sketches and design knowledge. Moreover, by following the concept of preliminary coding system which is based on the design process of industrial products, the coding scheme for architecture design will be presented in the near future.

References

Akin, Ö.: 1978, How do architects design? In J. C. Latombe (ed.), Artificial intelligence and pattern recognition in computer-aided design, North Holland, New York, pp.65-104.

Akin, Ö and Lin, C.: 1995, Design protocol data and novel design decisions. Design Studies 16(2), 211-236.

Christiaans, H. and Andel, J.: 1993, The effects of examples on the use of knowledge in a student design activity: the case of the 'flying Dutchman', Design Studies,14, 58–74.

Eastman, C. M.: 1970, On the analysis of intuitive design process, In G. T. Moore (ed.), Emerging methods in environmental design and planning, MIT Press, Cambridge, MA, pp. 21-37.:

Gero, J. S. and Neill, T. M.: 1998, An approach to the analysis of design protocols, Design Studies, 19, 21–61.

Kosslyn, S. M., Reiser, B. J., Farah, M. J. and Fliegel, S. L.: 1983, Generating Visual Images: Units and Relations, Journal of Experimental Psychology: General 112(2), 278-303.

Purcell, A. T. and Gero, J. S.: 1991, The effects of examples on the results of a design activity. In J. S. Gero (ed.), Artificial intelligence in Design, Oxford, Butterworth Heinemann, pp. 525-542.

Reed, S. K.: 1974, Structural descriptions and the limitations of visual images, Memory & Cognition 2(2), 329-336.

Schank, R. C.: 1986, Explanation Patterns: Understanding Mechanically and Creatively, Lawrence Erlbaum Associates, Hillsdale, NJ.

Schön, D. A. and Wiggins, G.: 1992, Kinds of seeing and their functions in designing, Design Studies 13(2), 135-156.

VISUAL KEYS TO ARCHITECTURAL DESIGN

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Abstract. This paper presents a new mechanism to access and interact with DY*N*AMO, a collective case base for architectural design developed as a Web-based tool. The system is fully operational since a few years in the context of architectural design education as well as for seminars on architectural theory. We have now developed a set of visual keys structured at the one hand according to the Vitruvian tripartition of architecture: Firmitas (structure, materials,…), Utilitas (building programme,…), Venustas (formal qualities/articulation, spatial configuration,…) to which we added Context (topography, site, budget, climate,...) as a supplementary dimension, and at the other hand including three levels of detail: single spaces, building blocks or master plan entities. Visual keys match the architect's designerly way of thinking. The visual keys are in fact nothing else than a graphical codification of architecture within the realm of architectural composition. The software, that has been developed so far, does not only allow users to access cases via the keys we have implemented, but it also provides a tool to sketch and submit their own keys.

1. The DYNAMO case base

DY*N*AMO (Dynamic Architectural Memory Online), initiated in 1996, is a fully operational case base for architecture, allowing to easily access design cases online (Heylighen, 2000). Within the context of several research projects its content has been and is expanding, while its architecture has been revised. Till today the case base is accessible through indices, which allow various (combined) searches depending on the interests of the users – designers, theorists, historians. Architectural designers browse 'at random'

in order to load their batteries, for creative action requires previous experience (Koestler, 1965). They can select specific cases by author or project name, or narrow their choice by specifying multiple criteria as shown in Figure 1. Architectural theorists on the other hand are frequently looking for currents and tendencies in architecture, for example the collection of houses that are representative for the twentieth century production in a given country. Historians as a rule are more interested in the diachronic evolution of buildings. Each of these user types have other expectations, demand other services from a case base and hence, access mechanisms adapted to their needs.

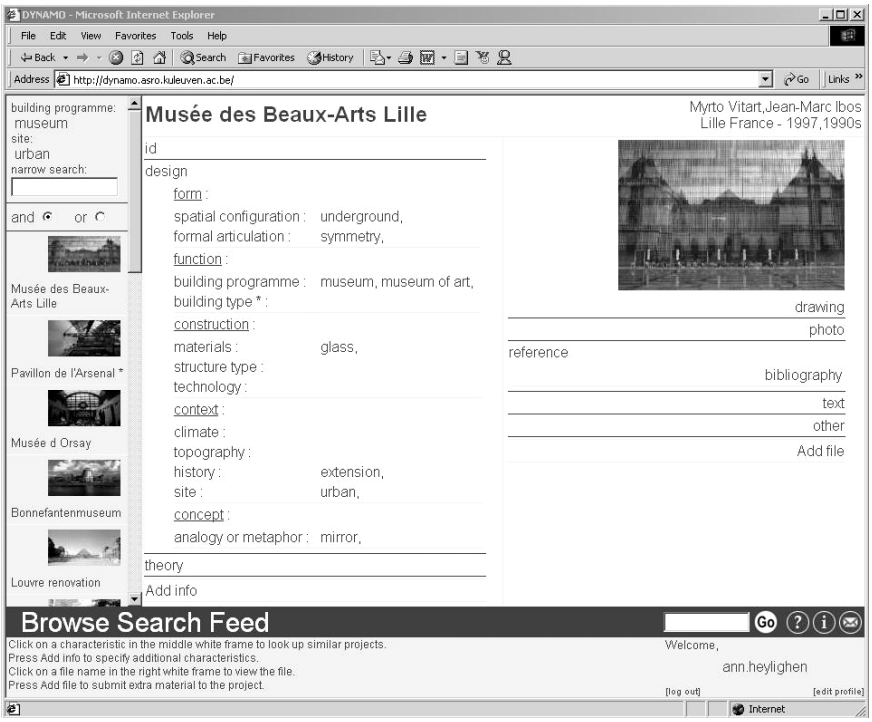


Figure 1: Screen shot of DYNAMO's search result when looking for a particular building program (museum) on a specific site (urban).

Today DYNAMO contains more than 180 projects related to different themes or programmes in response to ad hoc teaching demands. Up till now cases contain graphical data like plans, sections, elevations, drawings and alphanumerical information, yet in fact they can contain whatever can be communicated through the Internet. A crucial issue of debate in building such a case base is whether cases should be presented as such, i.e. as raw material, or rather as an interpreted reality, to be more precise as the result of analysis. Most schools of architecture have the subject of analysis on their curriculum, more and more in a digital version and therefore it seems a good

opportunity to share the results of these efforts within the wider community of architectural education. Most schools would be interested in these digital models allowing virtual 'promenades architecturales' through the building.

If a case goes beyond the raw material, then its modelling presupposes a lot of choices and is dictated to a large extent by the intended use of the case, by what questions will be asked. If, for example, you are interested in the daylight conditions in the National Assembly Building of L. Kahn in Dhaka, then the modelling should include these. If the circulation is very peculiar in a building, it should be easy to generate it from the model. So even in the case of 'raw' material, the digital realm asks for a clever data structure and/or layering of the model.

As far as software is concerned, DY*N*AMO is currently structured as shown in Figure 2. In essence, the tool consists of 3 major components: 1. a collection of design cases - the actual case base of DY*N*AMO; 2. a database (MySQL) that organises and structures these cases; and 3. a user interface to both consult and modify the case base. Cases and database are stored at the sever side; users interact with DY*N*AMO through a standard Web-browser at the client side.

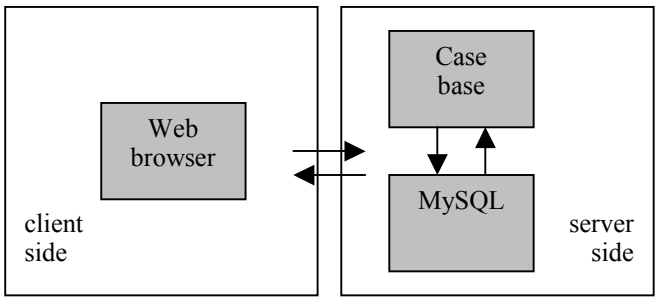


Figure 2: DY*N*AMO's 3 components

2. Designerly access for architects

Indices to access the cases are dictated by the type of users. What are the expectations of an architect or student in architecture who is willing to learn from past experiences, who is looking for inspiration while designing? The designerly way of thinking, quoting Nigel Cross (1982), is graphical, and proceeds through, in and with images in contrast with the 'numeracy' of engineers and the 'literacy' of linguists. Architects, like all visual oriented artists, create in a silent dialogue with their drawings and images. Therefore the content of DY*N*AMO's case base is primarily graphical. In order to enhance the comfort of use and avoid having to switch thinking modes between designing and consulting cases, a graphical interface has been designed and implemented.

3. Visual keys

The graphical interface is a collection of structured visual keys, covering most of the design categories that belong to the architect's vocabulary. In fact all together they represent a graphical codification of architecture, inspired by major architectural theoretical publications. The keys are presented as icons, and in order to guarantee an open system, a sketch tool has been built allowing users to create their own keys as shown in Figure 3. (Morisse, 2001).

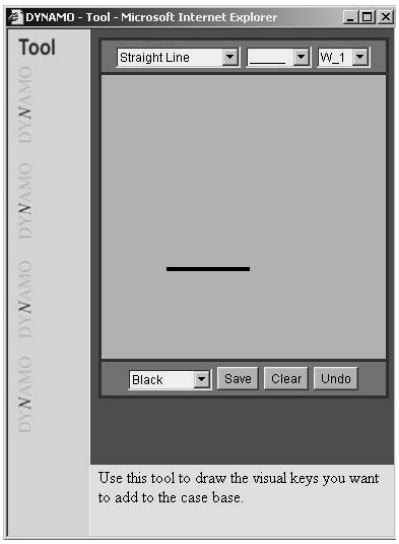


Figure 3: sketch tool to create visual keys.

However, because icons are not always univocal, a textbox pops up when hitting an icon. The visual keys provided by the system, as well as those added by the user, are linked to the database by their textual description that has to be input/assigned manually when creating a case. It is imaginable to automate this step by pattern recognition, but this has not been implemented. The keys have been structured along two major lines: first according to the Vitruvian tri-partition of architecture in Firmitas, Utilitas, Venustas (Rowland, 1999) plus the category Context and secondly, according to three levels of detail: the bigger scale or master plan at level 1, subsequently at level 2 the single building block and at the smallest scale the level 3 of individual rooms or spaces. These levels are based upon a general framework for CAAD, which spans the normal scope of architectural design as in Figure 4. (Neuckermans, 1992)

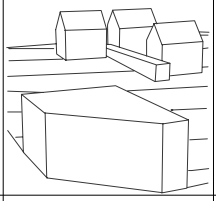
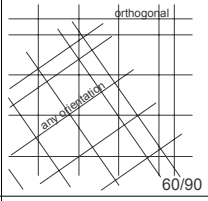
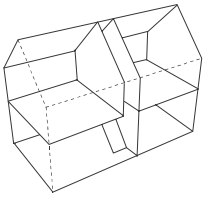
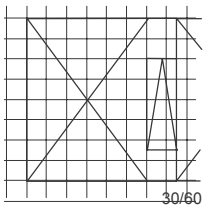
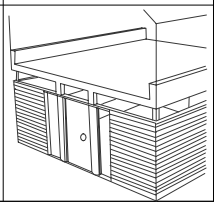
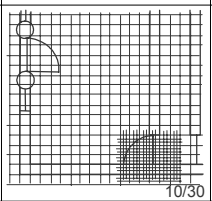
Building Program	Design Entities		Grids	Tests
	Name	Geometry and attributes	Topology and attributes	
Level 1 **MASTERPLAN**	∀ Basic building types ∀ Masterplan blocks ∀ Circulation axes ∀ Site contingencies			∀ Cost/m² or cost/m³ ∀ Surface/block ∀ Compactness ∀ Energy requirements ∀ Traffic ∀ Morphology ∀ Views and sights ∀ Shadowing
Level 2 **BLOCK or TYPE**	∀ Rooms or singular spaces			∀ Cost/m² based on ratios ∀ Surface and volume/space ∀ Temperature fluctuations ∀ Level of insulation ∀ Morphology
Level 3 **ROOM or SPACE**	Building elements: ∀ Wall ∀ Column ∀ Beam ∀ Arch ∀ Opening ∀ Door ∀ …			∀ Gross-nett surface/space ∀ Cost based on elements method ∀ Comfort prediction ∀ Daylighting ∀ Sunshining ∀ Morphology ∀ Elementary stability

Figure 4: A conceptual framework for CAAD, spanning 3 levels of detail: master plan, building block and room or space

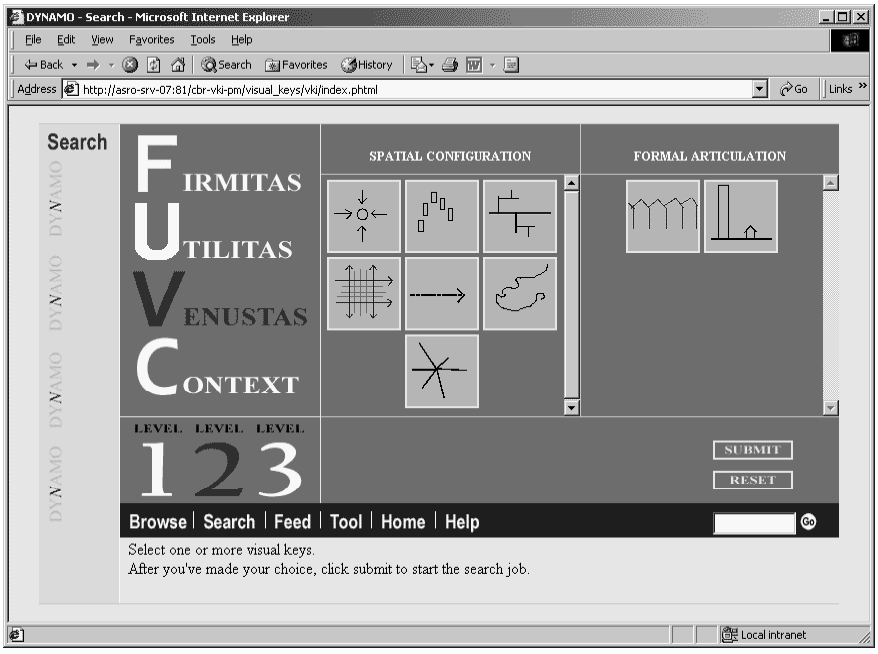
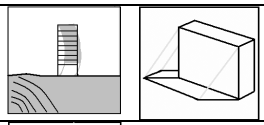
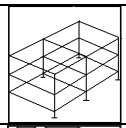
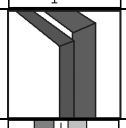
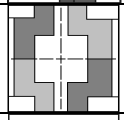
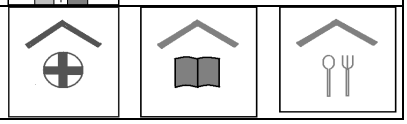


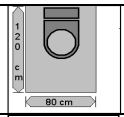
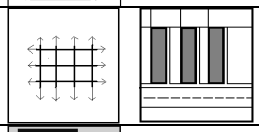
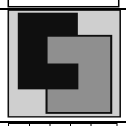
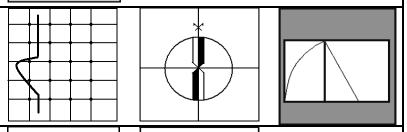
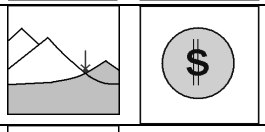
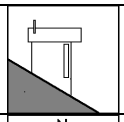
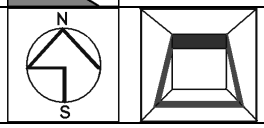
Figure 5 : example of DYNAMO's visual keys

Further refinements within each of these 12 categories (4 dimensions and 3 levels) have been inspired by the work of Christian Norberg-Schulz, Francis Ching, Rob Krier, Le Corbusier, Panerai and Castex, CI/SfB, Pierre von Meiss and others. From Genius Loci (Norberg-Schulz, 1980) we borrowed the idea of what makes a space a place. Norberg-Schulz identified 3 categories characterising a place: history, meaning and identity, from which in particular the last one serves our purpose. Identity, according to Norberg-Schulz, has to do with location, formal articulation, spatial configuration (see Figure 5). Icons for building programmes are inspired by those we made for BB/SfB, the national version of the CI/SfB building classification system that is widely used in Europe (De Troyer e.a., 1990).

'Architecture: Form, space and order ' by Ching (1978) still remains the seminal sourcebook on modern architectural composition and has inspired most of the icons describing the elements of architecture. The 'Elements of Architecture' by Rob Krier (1983) and the book of the same name by Von Meiss (1990) offer an interesting complement to that. From Le Corbusier and Jeanneret (1927) we borrowed the well-known icons of his 5 guidelines ('points') to a new architecture. As far as the graphical codification of urban spaces is concerned, Rob Krier's book (1979) provided us with a thesaurus of schemes derived from real cities. The books by Panerai and Castex (1997,1999) inspired us for the typology of urban block structures.

Table 1: visual keys' structure

Entry points		Textual descriptor	Iconic representation
Firmitas	Level 1	Seism Wind Insolation	
	Level 2	Skeleton Structural system Large span	
	Level 3	Building elements e.g. Cavity wall Materials	
Utilitas	Level 1	Public/private Open/closed Street/Square	
	Level 2	Building programmes e.g. hospitals	

	Level 3	Functions Activities Kitchen	
Venustas	Level 1	Grid Block - Ilôt Strip -'Barre'	
	Level 2	Types /Cluster Formal articulation	
	Level 3	Colour/Texture Symmetry Composition	
Context	Level 1	Landscape Climate Budget	
	Level 2	Site topography Microclimate Budget	
	Level 3	Orientation View Sunshine	

4. Summary and conclusion

In an attempt to fit better the architects' designerly way of thinking, we have developed a graphical user interface to access DY*N*AMO, an online collection of architectural cases. The software that has been developed, so far does not only allow users to access cases via visual keys we have implemented, but also provides a tool to sketch and submit their own keys.

Acknowledgement

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References

Barron, F.: 1969, Creativity, Encyclopedia Britannica, Vol.6, W. Baton, London.

Ching, F.D.K.: 1978, Architecture:Form, space and order, Van Nostrand, New York.

Cross, N.: 1982, Designerly ways of knowing, Design Studies, 3(4), 221-227.

De Troyer, F., Neuckermans, H. and Havenne, D.: 1990, BB/SfB tabellen 1990: klasseersysteem voor de bouwsector, Ministerie van Openbare Werken, Regie der Gebouwen, Brussel.

Heylighen, A.: 2000, In case of architectural design. Critique and praise of Case-Based Design in architecture, Ph.D. diss, KULeuven, Fac. of Engineering, Dept. of Architecture, Leuven.

Koestler, A.: 1965, The act of creation, Hutchinson & Co, London.

Krier, R.: 1979, Urban Space, Academy Editions, London

Krier, R. : 1983, Elements of Architecture – Architectural design Profile 49, AD 53,9-10

Le Corbusier: 1927, Les cinq points d'une architecture nouvelle, in W.Boesiger and O.Stonorov (Eds), Le Corbusier et Pierre Jeanneret, Œuvre complète 1910-1929, Edition d'architecture, Zuerich, 1946, 128-129.

Morisse, P.: 2001, Visuele sleutels voor Dynamic Architectural Memory On-line (DYNAMO), graduate's thesis, KU Leuven, Dept. of Architecture, Leuven.

Neuckermans, H.: 1992, A conceptual model for CAAD, Automation in Construction, 1(1), 1-6.

Norberg-Schulz, C.: 1980, Genius Loci. Towards a Phenomenology of Architecture, Academy editions, London.

Panerai, P., Castex J. and Depaule J.C.: 1997, Formes urbaines. de l'îlot à la barre, Editions Parenthèses, Marseille.

Panerai, P., Depaule J.C. and Demorgon M.: 1999, Analyse urbaine, Editions Parenthèses, Marseille.

Rowland,I., Noble Howe, Th.: 1999, Vitruvius Ten books on architecture, Cambridge University Press, 14

Von Meiss, P.: 1990, Elements of Architecture, Van Nostrand Reinhold (International)

THE VIRTUAL DESIGNER: THE APPLICATION OF VRML IN COLLABORATIVE DESIGN

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Abstract. At present the architectural design process contains many inefficiencies. The tools of the collaborative design process tend to lack the high levels of interaction and communication required. All approaches in the modern design profession point to the utilisation of virtual space to maintain effective collaboration on all production levels. It is no longer relevant for outdated forms of physical communication to be expected to provide optimum collaborative work in the digital era. A new approach is needed. Rather than redesigning the process, the alteration of how communication between team members occurs is more appropriate.

1. Introduction

This paper looks at the process of collaborative virtual design, undertaken to improve online architectural communication. Through analysing the needs of designers and addressing their responses to collaborative design scenarios a clear process of approach to optimising virtual communication can be developed. Over the past four decades, the realm of virtual reality (VR) has grown out of nothing more than a concept. Originally a nameless technology, VR is now perceived as a revolutionary form of technology in today's society, with an immense scope and variety of applications to which it is presently applied. The application of VR is a form of this technology but the essence of VR is essentially an experience. Recently, offshoots of virtual reality, have taken the limelight, becoming better known than the original technology. This has led to the creation of a false perception of what the meaning of virtual reality is. By finding the essence of virtual reality, the relevance of its influencing factors can guide the technology to a relevant application. This application is focused on not only utilising the facets of VR in the most efficient manner, but to gain the maximum advancement for the design process in all areas of collaborative virtual design.

2. The Nature of Virtual Reality

VR is no longer just the high tech and futuristic technology, for specialised application, which it has long been categorised as. The development of Virtual Reality Modelling Language or VRML as it is commonly known, as a hybrid of VR is enabling virtual reality to be utilised as the communication tool from which its full potential can be utilised. VRML is a programming language, which enables a user to view interactive 3D reality. Accordingly to VRML specifications web site VRML is a file format for describing interactive 3D objects and worlds… designed to be used on the Internet, intranets and local client systems."(VRML 97) The development of VRML was borne out of the need to expand the usability of VR and the desire to turn the web into a 3d immersive environment. VRML unlike its predecessor VR does not require the external hardware, which stereotypically defines the technology. With the ability to connect to any computer in the world and share, display and communicate a 3D environment, gives VRML a very powerful advantage over existing technology. From this point the options for reproducing static or dynamic virtual models in a standard interacting format created the opportunity for a wide range relay of complete immersive worlds for both viewing and manipulation. In order to understand what VRML can lend to collaborative design it is important to understand its relation to physical reality and to VR. When talking about computing and levels of interaction with physical reality there are several characteristics to compare. Professor Peter Thomas from the University of Western England sums this up quite well with his look at the paradigms of computing.

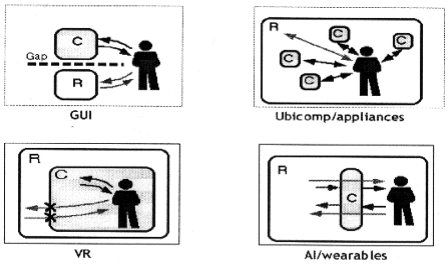


Figure 1a: *Image of Prof. Peter Thomas representing types of computer interaction.*

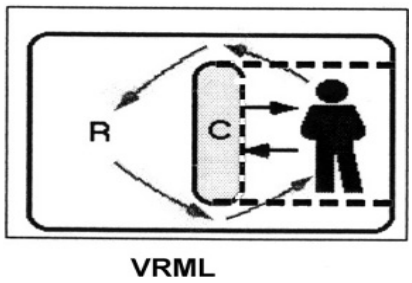


Figure 1b*: Adaptation of Prof. Thomas's image showing arrangement of VRML.*

Prof. Thomas's (2000) paradigm shows there are four main types of human-computer interaction (shown in Figure 1a). The images of the GUI and VR are most relevant to current discussion. The definition of VR involves the immersion of the user inside the computer. This is shown in Figure 1a where the user has access to reality only through the computer. The GUI on the other hand enables the user to interact with both the computer and physical reality simultaneously. As VRML is a hybrid of VR and in this sense it is more like the

GUI, with a gap between the two worlds. VRML attempts to bridge this gap with immersion and focus that VR uses to draw the user into the environment. So VRML falls into a category of its own, somewhere between GUI and VR (Figure 1b). This hybrid tends to incorporate the idea of levels of immersion in VR, but with the freedom to return to reality at any time. So essentially it relies upon the focus of the user. Therefore the characteristics of VR are present. It is these elements that maintain the focus of the user. The physical relationships to the GUI mean that VRML requires no more than an Internet capable computer to delve into the 3d immersed World Wide Web. The advantages of developing through VRML are its focus on its medium of transfer- the Internet. The characteristics of VR that VRML draws upon also lend themselves to the collaborative interaction. The three I's of VR indicated by Michael Heim (1998) show these attributes clearly."These defining characteristics boil down to the 'three I's' of VR: immersion, interactivity, and information intensity. Immersion comes from devices that isolate the senses sufficiently to make a person feel transported to another place. Interaction…. comes from the computer's lightning ability to change the scene's point-of-view as fast as the human organism can alter its physical position and perspective. Information intensity is the notion that a virtual world can offer special qualities like telepresence and artificial entities that show a certain degree of intelligent behavior." The ability to immerse a user in the experience presented, while supporting this experience with clarity of information and responsive information is paramount. These elements are inherently linked to the very structure of the software itself. The transferability across platforms through Internet browser, the synchronous nature of display maintained by relatively small file sizes, maintaining an immediacy of images. These attributes both in the nature of VRML and in its structure enable VRML to potentially be a powerful tool in design collaboration.

3. Application into Design

Design in any form is driven substantially by graphics. This is due to the importance of vision as a sense. As stated by McCullough (1996), "the eyes are the monopolists of the senses". But there is more to the issue that just this. The hand–eye coordination of a designer is paramount to the production of graphics, as vision the key to the client viewing these designs. So essentially designers use graphics as a medium to communicate their design intention. It becomes clear that for VRML to be effective in its application, it must address a level of virtual design and communication adequately, by either expanding the parameters of what is achievable with the available tools or being more efficient than previous techniques employed. To this end, the approach to implementing VRML into design development is rather simple. The intention is to gain the maximum advantage for the user with only the minimum impact and alteration to existing process.The model for a collaborative design studio incorporating VRML is formed from the present day organisational structure. To highlight this point the modern architectural firm will be examined. The 1990's model of a

design firm involves all team members having at least a basic level of computer skills. The diagram below (Figure 2) shows the high level of interaction between the members of all teams. The variation between the models of the two consecutive decades shows limited interaction between teams and CAD being used as an add-on tool rather than being highly incorporated in the design process. The 90's model tells a different story of high levels of interaction and computer/CAD usage. It becomes obvious that the design approach involves a more synchronous, virtually orientated office environment. It is this level of interaction and computer use that makes the proposal of incorporating VRML to improve communication skills relevant.

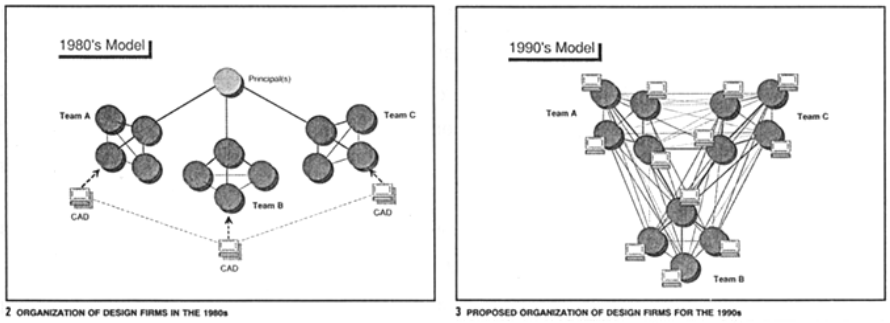


Figure 2: *Design Firm Organisational Models (Young, 1992)*

The proposed model still allows the firm to continue using the same approach to its projects as before, with VRML intended to be an additional application to save time and improve designs through better communication. The stage of establishing concept sketches and designs would remain unchanged; the main advantage would be during the design development and project documentation stages. Design development and documentation are generally the most time consuming in the project life-cycle stages according to Zwart (1995), "traditionally sketch design is 12%, design development is 13% and design documentation is 35%" of a project's length. From these figures VRML can potentially assist close to half of the average project's lifetime. By focusing upon design development and documentation, issues of technical computer constraints hampering design creativity in early stages can be assisted and in some cases avoided.

4. Implementation Approach

While many studies have been conducted into utilising virtual reality can be used to replace how design development and communication occurs, none have been focused on aiding the design profession in their present form, with limited impact. This is a feasible approach due to the nature of the design process, which can at times be highly personalised. To create a highly developed

communication tool, which stifles creativity and hinders the design process is counterproductive. The aim of this tool is to maintain the design process while improving communication and understanding of all parties. Rather than using VRML to reinvent the wheel, the advantage of the technology can come from its ability to make the wheel run smoother and more efficiently. Through analysis of the advantages and comparison to the present collaborative tools of the design industry, support for the use of VRML as a tool for the enhancement of the collaborative design process in architecture is provided. These were standardised into three streams, aimed at encapsulating the elements beneficial to the virtual collaboration process, while attempting to address issues of online design. The first stream is focused upon gaining a realistic mimicking of physical communication utilising real time video conferencing and a synchronous shared 2D sketch workspace. The second looks at extending the boundaries of collaboration beyond the standard two-dimensional interfaces used in online collaboration by incorporating VRML as an intuitive, synchronous 3d tool that affords use. Thirdly, the integration of seamless transitions between of overlaid 2d workspaces for images and sketches as would occur in a physical environment. Through analysis of three strands of virtual collaborative work relevant to design, support for a process of applying VRML was established. By integrating the utilisation of VRML seamlessly into the existing architectural design structure in this format, familiarity of physical discussion and maximised usability of incorporating VRML in the design process were achieved. Furthermore, through the use of a typical computer aided design (CAD) tool such as ArchiCAD the creation of VRML files from the initial virtual design are merely a change in file format. Integration with the existing design structures of an architectural firm are sustained and enhanced through greater functionality. The prototype involved a video conferencing system that allows VRML model display with a collaborative translucent overlaid whiteboard. The system needs to be multi-platform and enables users to exchange control over objects and applications. A high level of continuity between applications and movement while providing the designer with video, audio and graphical interface as an effective level of communication. In order to test these theories an initial study was conducted. This was aimed at testing the feasibility of such an approach to adapting the design process, rather than obtaining conclusive results. The results that were produced did provide future direction for further research to occur. Through testing this adaptation of the design process to virtual collaboration through qualitative analysis, the integration of collaborative streams identified as relevant for the nature of virtual design collaboration where supported. The experiment was recorded and analysed through video taped analysis, questionnaires of the study participants and the design outcomes at the end of the study.

5. The Results

The study resulted a considerable design progression during the study. Analysis and agreement upon the nature of the existing design occurred initially with little confusion. All parties were able to understand the details of the model with minor hassle; development of particular zones in project was the aim of the exercise and within the time required. The design objective was achieved and the system was successful, but this does not show that the tools for collaboration were the best for the job. What it does show is the use of VRML in collaboration can assist designers. The following points support this through comparison of findings to focused aims of collaboration. The findings of the questionnaire and the video footage revealed the following points:

- The communication focus of the system occurred with the audio connection and the whiteboard. The video was only used for initial connection and introduction between users.
- There were consistently high levels of interaction occurring between the two parties and also between the applications
- Intuitive interfaces for applications enabled fast learning curves for all parties involved in studies. This enabled the users to become familiar with the interfaces within a matter of minutes with the design collaboration rapidly progressing from an early stage.
- Simple quality of sketches was appropriate to the level of design discussion. The sketches and the same quality of those, which traditionally occur in a physical design meeting.

While the above are relevant, the true results in response to the collaborative aims are addressed in the following findings.

5.1. CREATING THE REALISM OF A PHYSICAL INTERFACE

The first of these is the input devices. When discussing design, in a physical meeting, a pen or pencil would create graphical discussion. For the virtual system, using a device like a graphics tablet would greatly improve the similarity to the physical process. The mouse does not have the same ability to control when compared to a graphical device, such as a pen, which is second nature to most designers. The nature of graphics interface heightens the quality of the development of ‘efficient’ graphics. This is supported by the argument that design is essentially driven by graphics as a medium for communication. The model interface would benefit greatly from a system such as the ComsoPlayer VRML viewer interface. This would enable the system to be even more intuitive and immersive. The interface on the tested system relied more upon three forms of movement, while CosmoPlayer enables six directional movement with more intuitive commands such as the seek function, the ability to undo a move and to reset view to the horizon. This adaptation would assist the future use of such a package. This would enable real-time movement and adaptation like can be achieved with a physical model.

5.2. CONTINUITY BETWEEN PHYSICAL AND THE VIRTUAL

An approach which was desired but not possible to test due to technical considerations was the ability to lay the transparent whiteboard over the model, just like butter paper or trace would go over a 2d or 3d drawing to add changes of locate points. The need for a transparent whiteboard to overlay the VRML model is supported by the actions of the participants in the initial experiments. In the process of design discussion an image was cut and paste onto the whiteboard and acted as a template for the design discussion. The implementation of a transparent/translucent whiteboard would allow the model to be moved to the required position with the whiteboard acting like the tracing paper. Rather than just providing the plans and elevations to sketch off the VRML model provides the ability to change the model appearance in 3D also. The virtual model also allows the opportunity to access details in the model from positions, which cannot be achieved, in a physical model. The dual use of sketching in both 2d and 3d further indicates a need to use the model and the whiteboard as one. The need for the view to be updated while synchronised with a designer speech and movements requires a simple interface for image change and also a highly usable navigation system for the VRML as mentioned in the first aim.

5.3. PRODUCING AND MAINTAINING EFFECTIVE COMMUNICATION

When working in a physical meeting the sketches and images produced can be taken with you. When documenting in a virtual meeting all notes and sketches are either in the whiteboard or a text box. This indicates the need to have a note keeper. In a virtual meeting the role of this individual would be to keep the points of verbal discussion linked to the appropriate sketches and screen shots of the VRML models location. It is very important for this to occur as the data is dynamic and the relevance of sketches can change due to modifications and different versions of ideas. As found with the user study conducted substantial data was verbally communicated, acting as linking and explaining the images produced. The images themselves were of a sketch like quality as often occurs in design meetings, seeming to contain limited meaning to the casual viewer, but with high relevance for those involved in terms of reminding and image recognition. It is for this linking that a note keeper would assist greatly, documenting for future communications.

6. Conclusion

In conclusion the initial study shows that the collaborative approaches utilising VRML were successful in conducting design development. While these results are not conclusive, they do provide a stepping-stone for further studies to occur, in order to establish a comparison of the level of effective communication when

compared to physical collaboration methods. All these approaches will assist in making the system more like the physical meeting space, without losing the power required to visualise the full details and volumes of the virtual models, with the realism of the physical world. Above all, this will assist virtual communication. In light of the findings established above, the proposal envisaged for application of VRML is highly appropriate and proved against the three aims of collaboration. Currently further exploration of the nature of collaboration required for design development is in progress. A prototype focusing upon the three streams of collaboration is under development to further establish the relevant aspects of design in the virtual realm. User testing of this approach will hopefully lead to a clear understanding of the issues of involved in user orientated virtual design collaboration.

References

Benedikt, M.: 1991, Cyberspace: First Steps. Cambridge, MIT Press, Mass.

Burks, L.: 1999,VRML and Representation: Designing Relationships Between Information and Form. http://www.gsd.harvard.edu/~lburks/f1/research/prep.html 31 November 1999.

Heim, M.: 1998,Virtual Realism. Oxford University Press, New York.

Hohnen, F.: 1995, Architecture and the Representation of Space, University of Queensland Press, Brisbane.

Ishii, H. and Ohkubo, M.: 1992, Design of TeamWorkStation. A Realtime shared Workspace fusing Desktops and computer screens, In proceedings from conferences on computer supported collaborative work, Toronto, p.367.

McCullough, M.: 1996, Abstracting Craft. MIT Press, Cambridge, Mass.

Thomas, P.: 2000, University of Western England, Bristol, UK, An Introduction to Handheld and Ubiquitous Computing Research, University of Queensland, 17 February 2000.

Young, R.: 1992, A Third Ware Practice, Progressive Architecture Vol. 73, No. 11, Nov, 106.

Zwart, T.: 1995, Computers in Brisbane Architectural Practice, University of Queensland Press, Brisbane.

CREATIVE DESIGN SITUATIONS

Artificial creativity in communities of design agents

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Abstract. This paper presents the outline of experiments with a behaviour-based computational model of creativity in design called *Creative Design Situations*. This model aims to allow the study of social creativity through the computational implementation of a community of creative design agents.

1. Studies of Creativity

Whilst the study of creativity in general has been a topic of interest in various disciplines, our current understanding of this distinctive human ability to create and innovate is still fragmentary (Runco and Albert, 1990). In design research, creativity has been the focus of a number of research efforts (Gero and Maher, 1989; 1993). However, there is still an inadequate comprehension of sufficient aspects of design creativity. This paper suggests that new approaches are needed to gain further insight into design creativity, particularly as a social phenomenon.

It is suggested that before trying to improve creativity in design, it is essential to know more about it, how is it produced and recognized, where and under what conditions does it occur, when does it start and finish, and what promotes or hinders it (Runco and Albert, 1990).

2. Experimentation

One feasible way of building a more complete understanding of creative phenomena is by carrying out comprehensive manipulation and

experimentation with the presumably numerous kinds of factors and processes that have been related to the occurrence of creative solutions throughout the research literature (Runco and Pritzker, 1999). This research presents a way of experimenting with creativity when seen as a complex system (Mataric, 1993), an approach that has yet to be better understood and applied in this kind of studies, and which could provide an important contribution towards the formation of a theory of creativity.

Under this view, the occurrence of creativity can be considered as consisting of emergent behaviour of a system that is not directly proportional to the sum of its parts. Thus, such difficulty to clarify the exact causes and conditions under which the creative event takes place has often caused it to appear surprising and inexplicable to some researchers (Gardner, 1993). This controversy could suggest, amongst other things, that creativity takes place in relation to certain system states within a multifaceted set of causes and possibilities, whose results are surprising only when the complete historical sequence remains inaccessible.

As with other complex systems such as the evolution of species or metazoan formation, the development, coherence, and persistence of creative systems could depend on extensive interactions, the aggregation of diverse elements, and adaptation or learning (Holland, 1995). And as in the study of such complex adaptive systems (CAS), general principles could rule creative behaviour, principles that research needs to disclose. The next section sets the foundations for a behaviour-based approach to experimentation with creative systems.

3. Behaviour-Based Model

Artificial Life, an example of behaviour-based experimentation, is described by Langton (1989) as the synthetic approach to biology. Rather than take living things apart, it attempts to put living things together, in this way arguing that certain phenomena are most appropriately treated by a synthetic approach where a logical form is abstracted from the natural problem and implemented in a computer program that serves as a laboratory to experiment with the determination of collective behaviour.

A behaviour-based study of creativity in design uses insights from artificial life to explore the dynamics of interacting information structures, not by attempting to ‘explain’ creativity as a kind of computer program (and in this way avoiding the quandary of computers being considered alive, intelligent, or creative) but rather by supporting informational universes within which dynamic populations of individuals engage in a form of creative behaviour (Pattee, 1996). Figure 1 illustrates a behaviour-based approach to modeling creativity in design. From the modeling of behaviours

in the microscopic dimension emerges the synthesis of collective behaviour of interest in the macroscopic dimension.

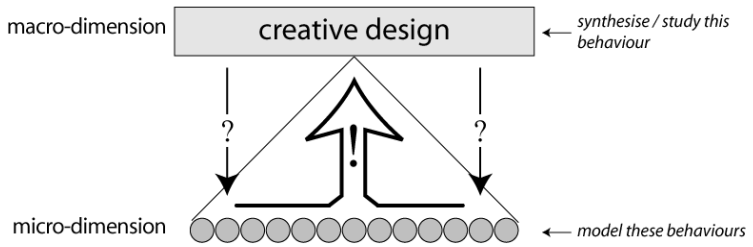


Figure 1. Behaviour-based bottom-up approach to modeling creativity; after Langton, 1989.

In artificial life models, the behaviour of animats is studied by focusing on aspects of individual conduct and the ensuing dynamics at the collective levels. Reproduction, forage, migration, climate changes, and other phenomena are abstracted from real animal species, implemented in experiments, run, and their results analyzed thus potentially providing insights into animal behaviour (Cliff et al., 1994) and robot design (Steels, 1990). Correspondingly, behaviour-based models of creativity need to address aspects of individual and collective human behaviour in simplified computer programs that facilitate the study of their occurrence and interaction; that is the aim of this approach to the modeling of creativity presented in the following section. Table 1 compares the behaviour-based approach to the knowledge-based modeling of creativity.

Table 1. Approaches to the computational modeling of creativity

Behaviour-Based Artificial Creativity	Knowledge-Based Artificial Creativity
Aims to reproduce creativity in order to study it	Aims to study creativity in order to reproduce it
From synthesis to theory analysis	From theory analysis to synthesis
Assesses soundness of theories	Assesses soundness of results

4. Creative Design Situations

This section presents a model of creativity in design called Creative Design Situations (CDS) that aims to serve as an experimental framework by which different insights and various thought experiments can be implemented in

computer applications that facilitate the exploration of hypotheses potentially associated with creative behaviour in design. The CDS model is based on a possible set of socio-cognitive components that have been correlated to the occurrence of creativity by relevant studies that characterize this as a multidimensional phenomenon in which genetic, cognitive and social levels interact (Findlay and Lumsden, 1988).

The term *situation* is used in the CDS model to refer to the state of the design and its relation to the designing environment. What this notion encapsulates is that creativity is not an inbuilt property of a design (like its color or the material it is made from), but exists only as a function of a system composed by the interaction between the design and its environment. Such an environment can include the design agent, the evaluator, the context, the period of time, the means of interaction between agents, and any other aspect of interest in the study. Under this view, creativity transcends the individual reasoning process to include its *situatedness* (Clancey, 1991). As a result, it allows that the same design can be considered creative or not under certain circumstances, within certain periods of time, in relation to other existing designs, and by some evaluators, etc.

In descriptive terms, a Design Situation (DS) can be seen as a transitory worldview within which a design solution is generated or evaluated by the individual(s) found in that situation. A change of any given element that comprises a DS could yield a different relation between the design and its environment, and so a design could succeed or fail a creative assessment even if the object itself were left unchanged – since its situation did. A key role in a DS is played by the designer (a design agent), who may directly construct its DS or adopt an existing DS, or elements of it. Design agents that share a common DS are considered members of a community of designers. More formally, a DS can be defined by at least four essential components:

1. problem representation
2. design space
3. design processes
4. evaluation criteria

When a design agent constructs or adopts a DS, at least these four components are either implicitly or explicitly present significantly shaping the outcome – and thus importantly play a role in determining its final creativity. Problem representation stands as a working formulation or interpretation that can either be individually constructed or socially accepted. This represents a bounded way of dealing with a potentially infinite set of possible descriptions of a problem, giving place to a subsequent space of possible designs (Gero, 1996) Design operations refer to the available means of transforming the problem representation during the design process. This is

referred to as design skill or techniques. Evaluation criteria are part of a DS by providing the parameters against which design solutions are evaluated. These criteria are used to evaluate current solutions and serve as a point of reference for past as well as for the generation of future possible solutions. However, such criteria are not fixed but are part of the construction of the design situation. In sum, from a situated point of view, the eventual generation of a creative solution is associated to the change in the way of interpreting the problem, the design means available, the resulting set of possible solutions, and the new applicable evaluation criteria.

Under such a definition, a Routine Design Situation (RDS) is one within which well-known solutions are generated, and is shared by a large number of members of a community. In contrast, the components of a Creative Design Situation (CDS) are modified so that solutions that are new and adequate are made available. A CDS could be seen as a DS in formation that needs to be fully explored, the condition of its components, their new possibilities and limits, being better understood only through the synthesis of further design solutions. At a societal level, a CDS is increasingly adopted by individuals that shape or reshape their community. The CDS model suggests that the production of creativity in design is strongly associated to the situatedness of the design and that a Design Situation could move from routine to creative throughout time.

A design solution of a CDS does not originate from the same problem representation, is not contained in the same design space, generated via the same operations and measured against the same criteria as a routine solution. In this sense, the idea of Design Situation stands as a construct to denote a design space that is constantly constructed and modified as part of the interaction with a changing environment, i.e. akin the problem-finding and problem-solving interaction suggested in the co-evolutionary model of design by Maher and Poon (1996). Further details of the CDS model are presented elsewhere (Sosa, 2001).

A feasible CDS experimental program contains the following basic elements: a population of individuals or design agents; a common environment; interaction mechanisms between such agents; a design task, and a set of design solutions. In such an experimental program, different behaviours can be observed and manipulated. Of particular interest are the emergence, diffusion and exhaustion of a Creative Design Situation. Various questions can be explored in a CDS program: How can individuals introduce novelty into their society? How can a problem be reformulated by both innovators and assessors? How can a creative artifact become routine over time? What individual, social, and environmental conditions may facilitate or hinder creative behaviour? What is the degree of innovation supported by a society? What roles may assessment and misjudgment play in the definition of creativity? How may a community continuously self-define

what counts as creative? How can communities and cultures be formed and reshaped after a creative solution? How can the body of shared elements in a community be transformed? How can novelty be individually driven and socially demanded? In sum, what low-level creative components may take part in the emergence of group-level innovation? And ultimately, how might these findings guide new support and learning systems in design?

5. CDS Experiment Framework

Consider an experimental setting as follows:

- an initial representation of the problem formulation,
- a set of existing solutions that follow a series of design requirements,
- a population of design agents with individual means of interpreting, representing and transforming the object geometry,
- a design task consisting in the generation of solutions that conform to the interpreted design requirements and that are different to the existing solutions,
- individual mechanisms for interpreting design requirements as well as for generating and sharing new representations among design agents,
- a common environment with variables such as communication mechanisms, performance threshold, credit allocation, evaluation criteria, etc.
- an observer to track and graph individual solution generation and collective performance over simulated time steps.

In a multi-agent system of this kind, agents can be biased with different characteristics to facilitate the study of various emergent phenomena and their correlation to the design situation A key phenomenon of interest is the formation of communities of agents, i.e., groups of agents that share commonalities, and their role in Design Situations. The experiment should provide evidence for the development of Design Situations from routine to creative and back to routine, as well as the capacity of a population of design agents to produce and assimilate creative solutions. Other experimental settings include homogeneity and heterogeneity in populations of design agents, direct and indirect communication processes, incremental and non-incremental design processes, competition between different DS in formation, and cooperative phenomena among members of a community.

The kinds of results that are expected from these experiments are located in the group level phenomena related to creativity that are observed by regulating individual and environmental characteristics, as well as the

feedback from the societal level to individual decision-making, i.e. the agents' situation awareness. From these results, relevant abstractions can be elaborated to describe components and interactions of such in vitro creative system, principles that may contribute to a theory formation of creativity.

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References

Clancey, W.: 1991, Review of Rosenfield's The Invention of Memory, Artificial Intelligence 50(2), 241-284.

Cliff, D., Husbands, P., Meyer, J-A. and Wilson, S. (eds): 1994, From Animals to Animats 3, Third International Conference on Simulation of Adaptive Behaviour, MIT Press, Cambridge.

Findlay, C. S. and Lumsden, C. J.: 1988, The Creative Mind, Academic Press, Orlando.

Gardner, H.: 1993, Creating Minds, an Anatomy of Creativity Seen Through the Lives of Freud, Einstein, Picasso, Stravinsky, Eliot, Graham and Gandhi, Basic Books, New York.

Gero, J. S.: 1996, Creativity, emergence and evolution in design: concepts and framework, Knowledge-Based Systems, 9(7), 435 –448.

Gero, J. S. and Maher, M. L. (eds): 1989, Preprints Modeling Creativity and Knowledge-Based Creative Design, Design Computing Unit, Department of Architectural and Design Science, University of Sydney, Sydney.

Gero, J. S. and Maher, M. L. (eds): 1993, Modeling Creativity and Knowledge-Based Creative Design, Lawrence Erlbaum, Hillsdale, New Jersey.

Holland, J. H.: 1995, Hidden Order, How Adaptation Builds Complexity, Addison-Wesley, Reading.

Langton, C. G.: 1989, Artificial life, in Langton, C. G. (ed.): Artificial Life: Proceedings of an Interdisciplinary Workshop on the Synthesis and Simulation of Living Systems, Santa Fe Institute Studies in the Sciences of Complexity, Addison-Wesley, Redwood, pp. 1-47.

Maher, M.L. and Poon, J.: 1996, Modelling design exploration as co-evolution, Microcomputers in Civil Engineering, 11(3), 195-210.

Mataric, M. J.: 1993, Designing emergent behaviours: from local interactions to collective emergence, in Meyer, J-A., Roitblat, H. and Wilson, S. (eds), From Animals to Animats, Proceedings of the Second International Conference on Simulation of Adaptive Behaviour, MIT Press, Cambridge, pp. 432 –441.

Pattee, H. H.: 1996, Simulations, realizations, and theories of life, in Boden, M. (ed.), The Philosophy of Artificial Life, Oxford University Press, New York, pp. 379 –393.

Runco, M. A. and Albert, R. S. (eds): 1990, Theories of Creativity, Sage Publications, Newbury Park.

Runco, M. A. and Pritzker, S. (eds): 1999, Encyclopedia of Creativity, Academic Press, San Diego.

Sosa, R.: 2001, Creative Design Situations, Research Proposal submitted for the degree of Doctor of Philosophy, Key Centre of Design Computing and Cognition, University of

Sydney, Sydney, Australia. Available at: http://www.arch.usyd.edu.au/~rsos7705/sosa-proposal.pdf

Steels, L.: 1990, Cooperation between distributed agents through self-organisation, in Demazeau, Y. and J. P. Muller (eds), Decentralized A.I.: proceedings of the First European Workshop on Modelling Autonomous Agents in a Multi-Agent World, Cambridge, England, 1989, North-Holland, Amsterdam, pp. 175-196.

A MEMORY SYSTEM FOR A SITUATED DESIGN AGENT BASED ON CONSTRUCTIVE MEMORY

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Abstract. Situated design agents require new types of memory. The design of a memory system for use in such a design agent, based on the notion of constructive memory is proposed. The specification of the memory system is derived from the architecture of a situated design agent. Cognitive studies of the human memory system provide the functional and behavioural characterization of the memory system.

Introduction

This paper outlines the conceptual architecture of a memory system for a situated design agent based on the paradigm of constructive memory in design (Gero, 1998; 1999a; 1999b). The incorporation of this memory system facilitates the creation of a computational design system with performance that matches normal design systems and has the ability to operate in an environment for which the system has not been directly programmed. Through a set of learning capabilities and the interaction with the environment, the agent is able to learn from experiences and ground what it knows through these experiences. This is a fundamentally different approach to the programmer encoding into the agent all the knowledge a priori, which is the approach adopted when using expert systems.

The Constructive Memory Paradigm

Memory construction occurs whenever a design agent uses a past experience in the current design environment in a situated manner. Any information available in the current design environment is used as cues in this construction process. Associated memories are constructed and grounded

according to the current interactions between the agent and the environment.

This behaviour of a constructive memory system within a situated environment has the following characteristics:

- memory operates as a dynamic process, it is not a static imprint to be stored in a specific location and retrieved for used later;
- the operations of the memory system are not predefined, they are influenced by the situatedness of designing;
- construction of memories do not rely on the exact matching between what the agent has in the memory system and the current designing environment; and
- memories that are constructed may not match the original experience exactly as it was first experienced, but change according to when, where and what the memory system is cued with.

The Memory System

The various components of the memory system are derived from cognitive studies of the human memory system. In particular the following models of human memory are adopted:

- modal model of human memory system (Atkinson & Shiffrin, 1968);
- multiple-component model of long-term memory (Baddeley, 1999); and
- multiple-component workspace model of the human working memory (Logie, 1995).

0[1] illustrates the architecture of the proposed memory system for the situated design agent. The paths in 0 are shared between processes to avoid overcrowding the diagram. They can be taken as directed association between two entities, i.e. information or instructions flow in the indicated direction.

Working Memory

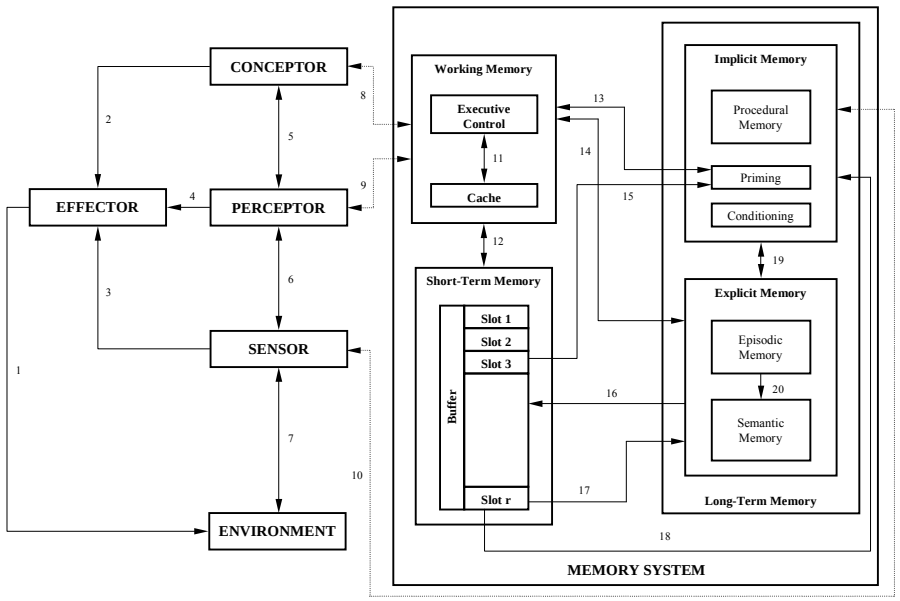
The working memory is a workspace for reflective and reactive processes where explicit design-based reasoning occurs. It is also the working environment where executive control functions are performed. These processes selectively alter and/or add information to the working memory based on the content of the LTM (14) [the numbers in parentheses refer to the paths in Figure 1] or STM (12). Information within the working memory are combined with the stored knowledge and experiences, manipulated, interpreted and recombined to develop new knowledge, assist

[1] The functional components of the architecture do not imply that different types of memory reside in different location within the agent. The boundaries between different forms of memory are there to highlight the functions of different type of memories. All these memories are used to construct a design situation.

learning, form goals, and support interaction with the external environment. Knowledge and experiences accumulated are available for use in the immediate task and once activated, they can then be manipulated for extraction of novel information that had not been stored explicitly in the past. The behaviours of these operations are influenced by: the external environment; the interactions between the agent and the environment; and the internal state of the agent.

The reasoning that occurs within the working memory is design related. It includes synthesis processes such as analogy, combination, mutation and designing from first principles (Rosenman & Gero, 1993) and reformulation processes (Gero, 1998) that deal with re-parameterization and parameter expansions. These operations of the working memory (explicit reasoning) are based on three main components:

the *executive control*: where the hub of the agent control processes is located;
the STM and LTM: where knowledge and experiences of the agent resides ((14)and (12)); and
the *cache*: that provides the buffering for the reasoning processes (11).



Conceptual architecture of a computational memory system (numbered paths are indicated as (#) in the text where # is the number as shown in the diagram)

The control processes within the executive control are involved in the organization, coordination, manipulation, movement and comparison of information and knowledge (derived from the environment or from the explicit memory) for design related reasoning. These processes deal with:

strategy selection and hypothesis-testing procedures associated with concept formation problems during conception, perception, hypothesizing, expectation and devising (Gero & Fujii, 2000);

the coding of percepts during perception where related stored knowledge and experiences from LTM or STM are activated and constructed within the working memory to allow the interpretation of current percepts in the current design session; and

tasks where there is a clear solution (reactive process) based on the current bias.

Inputs arrive from:

the conceptor (8) and perceptor (9) during conception;

the perceptor (9) during perception;

the LTM (14) and STM (12) when they play host to activated representations and procedures from them.

All of the above inputs are subjected to biases (13) before they are processed within the working memory system. The bi-directional path (13) between the priming component and the working memory models the effect of using the default bias or the setting of a predefined bias.

Short-Term Memory

The structure of the short-term memory (STM) is modeled as a short-term, fixed-size buffer (0) that captures the limited-capacity characteristics of the STM. The content of the buffer is constructed from the memory trace that enters the STM. The path (17) from the buffer to the LTM indicates the build up of a long-term trace due to the memory trace's level-of-processing. The slots in 0 are used to indicate the notion of the relative level-of-processing of the various traces within the buffer.

Both STM and LTM are used in the construction of memories in the working memory during the reflective and reactive processes ((12) and (14)). The differences between memory traces residing in the STM and LTM lie in the fact that memories in the STM are not as readily recalled in the memory construction process as compared to memory traces in LTM.

The STM serves as a gateway into and out of the LTM. The path into the LTM occurs when memory traces are transferred from the working memory to the LTM through the STM. As soon as a design situation or design experience has been constructed and served its purpose within the working memory, it is transferred into the STM as a new memory trace (12). Memory traces in the STM are integrated into the LTM gradually through their level-of-processing (17). STM acting as a gateway out of the LTM occurs when memory traces in the LTM that are not grounded frequently are transferred into the STM (16) and out of the memory system. These two actions model the phenomena of long-term learning and the phenomena of "use it or lose it" in human memory system.

The amount and form of memory traces that are transferred from the STM to LTM (17) are primarily a function of their level-of-processing. For a memory trace to be transferred to long-term memory, it must be go through a series of encoding levels. Active processing of a memory trace through its frequent association with existing memory traces within the LTM and its grounding according to (matching with) the current design situation, produce durable short-term memories. As the durability of a memory trace increases, its level of encoding increases. The increase in level-of-processing of a specific memory trace facilitates its inclusion into the LTM. This simple formulation captures the important characteristic of long-term learning in which a process of encoding material in terms of prior experiences and grounded usage produces comparatively durable and readily retrievable memory traces.

Long-Term Memory

The long-term memory is a relatively permanent repository for memory traces. Memory traces stored here do not decay and disappear as readily as those in the STM. New memory traces about design situations and design experiences are encoded into the LTM after they have been processed in the working memory and STM. To influence subsequent explicit behaviour, the memories within the LTM and STM are constructed and brought back into the working memory where it becomes part of the reasoning process.

Long-term memory refers to all effects of prior experiences and knowledge on subsequent behaviour of the situated design agent. This behaviour is classified as *reflective*, *reactive* or *reflexive*. Explicit memory systems provide memories for reasoning involving the working memory (reflective and reactive processes) while implicit memory systems deal with memories that affect the reflexive behaviour of the agent (the reflexive processes).

Explicit Memories

The reflective and reactive aspects of the situated design agent are based on explicit memory. Explicit memory consists of a semantic and an episodic memory subsystem. Semantic memory handles design knowledge while the episodic memory deals with the memories of design situations and design experiences.

Requests for explicit memories and transfer of the constructed memories occur through process (14). These operations are subjected to the bias activated at the current point in time (13). Explicit memories that are not

subsequently grounded are transferred to the STM before they are purged from the system (16). On the other hand, memories in the STM that have passed through a series of processing (level-of-processing) are transferred to explicit memory (17) for longer retention.

Episodic memory: deals with the storage and construction of memory traces related to design situations and design experiences. Once a new design situation or a design experience has been constructed and used within the working memory, it is stored in the STM as a new experience where it is subjected to several levels of processing before it is transferred into the episodic memory (17). The content of the episodic memory is also subjected to generalization (20). A common set of design experiences is compiled into a general design rule and the original experiences may be removed from the system.

Semantic memory: deals with general principles and refers to the acquisition, storage and usage of design knowledge. These include both general and specific knowledge related to designing. General design knowledge is domain independent and includes knowledge such as those are based on the generic FBS framework. Specific design knowledge is that which deals with a particular domain such as knowledge related to Design for Assembly and Design Simplification. All of this knowledge is grounded according to the agent's current internal state in relation to the current environment and is subjected to addition, modification, updating, replacement and removal as the agent learns new knowledge. Various possibilities for these operations include:

- knowledge gained through explicit learning processes that occurs during reflective and reactive process (14);
- knowledge (without contextual information) generalized from a common set of design experiences to form semantic knowledge that describes the underlying principles of the experiences (20); and
- knowledge transfer from implicit memory after it has been learned implicitly (19).

Implicit Memory

The implicit memory component captures knowledge expressed through performance rather than through recall and adaptation (semantic memory) or construction (episodic memory). Experiences are accumulated in behavioural changes. The reflexive behaviour of the agent is based on the implicit memory system. Implicit memories are taken as memories that are not used explicitly within the working memory during reasoning. These memories are information acquired previously that influences the agent's

behaviour or reasoning process either directly or indirectly.

Procedural memory: contains process knowledge on how to perform a specific design task. This knowledge about processes can be taken as the design skill that an agent has. With practice, these skills can be improved. The improvement is retained (remembered) from one practice session to the next using the feedback from the working memory (18) even though the information remembered is used in a reflexive manner later ((3) via (10)). If necessary, the knowledge learned is used together with those in the semantic memory if its application into the current situation needs to be considered together with other knowledge.

Priming: is the process that activates (biases) one or more existing memory traces by a stimulus (the priming stimulus) presented to the working memory system (13) and it influences the subsequent perception (9) and reasoning process (8). The priming stimulus originates from the memory traces contained within the LTM or STM ((15) and (19)) and it allows activated memories in the STM or LTM to be constructed into the working memory more easily after the priming experience than before ((12), (14)).

Conditioning: provides the reflexive behaviour to the agent by matching the pre-conditions of the rules it contains with the conditions of the environment and applying those rules when applicable. The agent's behaviour is affected directly by this reflexive action in the reflexive operation ((7), (10), (3), (1)). Common reactive operations that are frequently used are transferred to the conditioning component (18) so that they can behave in a reflexive manner without explicit reasoning in the working memory. The learning of new rules either by creating entirely new rules or by modifying/replacing existing rules will result in the creation of an artificial grammar. This occurs through an implicit learning process such as classical conditioning (Pavlov, 1960) or operant conditioning (Skinner, 1938).

Discussion

This paper has proposed a theoretical framework for the design of a constructive memory system for use in a situated design agent. The next phase of the research entails the implementation of the ideas presented here. The interactive activation and competition (IAC) network (McClelland, 1981) has been identified as a possible mechanism to implement the characteristics of the memory system. Once the memory system has been

implemented it can be used to further test the concepts of situated design agents.

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References

Atkinson, R.C. and Shiffrin, R.M.: 1968, Human memory: A proposed system and its control processes, in K.W. Spence (ed.) The Psychology of Learning and Motivation: Advances in Research and Theory, Academic Press, New York. pp. 89-195.

Baddeley, A.D.: 199,) Memory, in R.A. Wilson and F.C. Keil (eds), The MIT Encyclopedia of the Cognitive Sciences, MIT Press, Cambridge, Mass. pp. 514-517.

Gero, J.S.: 1998, Towards a model of designing which includes its situatedness, in H. Grabowski, S. Rude and G. Green (eds), Universal Design Theory, Shaker Verlag, Aachen. pp. 47-56.

Gero, J.S.: 1999a, Constructive memory in design thinking, in G. Goldschmidt and W. Porter (eds), Design Thinking Research Symposium: Design Representation, MIT, Cambridge. pp. I.29-35.

Gero, J.S.: 1999b, Recent design science research: Constructive memory in design thinking, Architectural Science Review 42: 3-5.

Gero, J.S. and Fujii, H.: 2000, A computational framework for concept formation in a situated design agent, Knowledge-Based Systems 13(6): 361-368.

Logie, R.H.: 1995, Visuo-Spatial Working Memory, Lawrence Erlbaum: Hove.

McClelland, J.L.: 1981, Retrieving general and specific information from stored knowledge of specifics, Proceedings of the Third Annual Meeting of the Cognitive Science Society, Erlbaum, Hillsdale, NJ. pp. 170-172.

Pavlov, I.P.: 1960, Conditioned Reflexes: An Investigation of the Physiological Activity of the Cerebral Cortex (translated and edited by G.V. Anrep.), Dover Publications: New York.

Rosenman, M.A. and Gero, J.S.: 1993, Creativity in design using a design prototype approach, in J.S. Gero and M.L. Maher (eds), Modeling Creativity and Knowledge-Based Creative Design, Lawrence Erlbaum, Hillsdale, New Jersey. pp. 119-148.

Skinner, B.F.: 1938, The Behavior of Organisms: An Experimental Analysis, Appleton-Century: New York.

FROM SIMULATION TO STIMULATION

Stimulative Design Computing Learning & Teaching Environment based on Multiple Representations

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Abstract. Design computing is an interdisciplinary field that centers on the intersection of design, computer science, and cognitive science. These multi-dimensional faces of this new paradigm necessitate a mutual understanding of computing and design as a whole, which are usually conceived as separate stages of computer-mediated design. This paper explores the use of multiple representations in stimulative design computing learning and teaching environment. This paper starts with an overview of computer-mediated collaborative learning, multiple representations and learner-centered design. Then issues related to the methodology in implementing the system are discussed. Agent models and prototype of the above computer-mediated collaborative learning system are constructed. The research is under progress.

1. Computer-Mediated Collaborative Learning

In recent years, educational research had attempted to determine under what circumstances collaborative learning is more effective than learning alone, and more recently, numerous studies have focused on computer-mediated collaborative learning. In psychology, interest in collaborative learning is related to the emergence of new theories such as “share cognition” and “distributed cognition”. These theories move away from the view traditionally held in cognitive science according to which human cognition is bound inside individual heads. The word “collaboration” is also used very frequently in computer science to describe the interactions among artificial agents (Dillenbourg, 1998).

2. Multiple Representations

In learning declarative knowledge and problem solving skills, multiple representations such as verbal, graphical and mathematical representations, knowledge at different levels of abstraction (e.g. qualitative and quantitative, specific cases or general models) are involved (van Someren et al., 1998). Seel and Dörr (1994) have discussed the distinctive relationship of supplantation of mental images through graphics and the instructional effects on spatial visualization skills of adults. Boshuizen and Schiff (1998) have discussed the issues of problem solving with multiple representation by multiple and single agents. This coordination of multiple representations is a topic that has not received as much attention in cognitive science as it deserves. There is clearly a gap that must be bridged between current education systems, in which the use of multiple external representations may actually hamper learning and expert performance, which is characterized by the ability to shift among different internal representations of a situation (Markman, 2000).

3. Learner-Centered Design

Learner-centered tools address the conceptual distance that lies between the audience of learners and the work practice in which they are engaged. Quintana, C et al. (2001) suggested that by developing scaffolding strategies informed by constructivist learning theories, a learner-centered tool incorporates support that allows a learner to participate in a new work practice to develop an understanding of the practice. The use of constructivist and social constructivist theories in learner-centered design (LCD) differs from the past efforts to design software tools for learning. Computer-aided instruction (CAI, based on behaviorist principles) and intelligent-tutoring system (ITS, based on information processing psychology) have attempted to package educational components that can train learners. Many CAI systems use a more information-transfer, passive model of learning. And ITS approaches can be less useful in loosely structured, wide-ranging work practices. While useful in more constrained fields like geometry and algebra, ITS tools can be difficult to implement for less constrained work activity. The key is that learner-centered tools should scaffold active participation by the learner in new work practices of all kinds.

4. Stimulative Design Computing Learning & Teaching Environment

Design computing is an interdisciplinary field that centers on the intersection of design, computer science, logic and linguistics. These multidimensional faces of this new paradigm necessitate a mutual understanding of computing and design as a whole, which are usually conceived as separated stages of computer-mediated design, i.e., Computer application and computing considered as the production force and design considered as the product for presentation. Bliss et al. (1999) addressed the nature of the influence of technology on learning, focusing especially on information technology and how it can influence any type of learning situation. Eastman (2001) has put forward the importance of cognition in design education. By means of the Vygotskian Inspired System (VIS), Luckin (1999) discussed the stimulative characteristics of learning with and by machines in assisting child-computer collaboration in the zone of proximal development.

Inspired by the above notions of computer-mediated collaborative learning, multiple representations and learner-centered design, in this research, interactions among artificial agents and human being in design computing learning is considered. In this paper the use of the above notions in stimulative design computing learning and teaching environment is explored.

5. Agent and Prototype Development

As shown in figure 1, an interactive and real-time design computing learning system agent model is constructed. By interactively manipulating the various attributes, codes, parameters and digital media contents in a distributed system, learners are gradually exposed to the mutual relationship of representational digital multimedia and the underlining programming syntax. The system combined the interactive coding verification capacity of visual software development utility such as Visual Studio and interactive multimedia manipulability of authoring utility such as Flash, with the introduction of 3D real-time simulation capacity for collaborative design computer learning in a distributed environment.

The first human computer interface (HCI) tools were developed using programming languages that were interpreted: Smalltalk (Tesler, L., [4) and then Dlisp (Teitelman, W., [5]). The interpreted language enables the developer to rapidly prototype different user interface ideas and immediately makes changes, which provides fast turnaround. With the rise of C and C++, most user interface development migrated to compiled languages and these capabilities were lost (Myers, B., Hudson, S.E. and Pausch, R., [6]). Researchers have investigated ways to bring back these advantages, resulting

in the scripting languages such as tcl/tk (Ousterhout, J.K., [7]), Python (Lutz, M., [8]) and Perl (Wall, L. and Schwartz, R.L. [9]). Nowadays, popular scripting languages such as JavaScript and VBScipt are providing interpreted capabilities. Combining scripting capabilities with components and an interface builder had proven to be a particularly powerful approach.

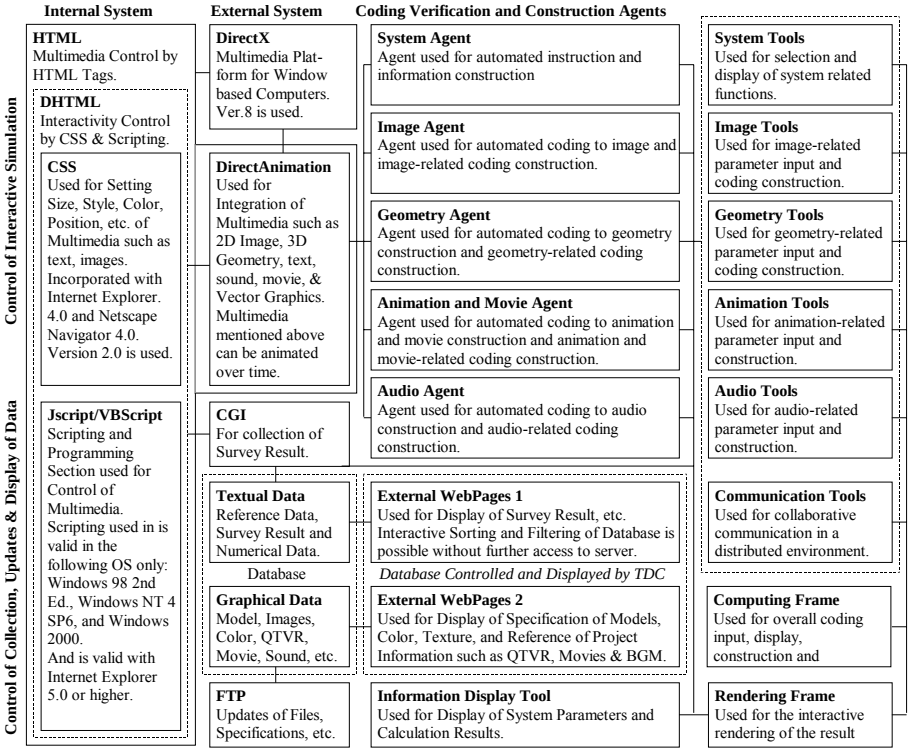


Figure 1. Prototype Development

Based on the use of JavaScript, VBScript and DirectX Scripting in combination with the DirectX multimedia platform in a web-based distributed environment, an interactive design computing learning system is constructed. Learners can interactively predict and evaluate the combined effect of digital multiple representations of multimedia contents (qualitative, semiotic, semantic) and programming codes (quantitative, mathematical presentation, syntax) real-time in a distributed environment. The aim is to expose the underlining mutual relationship of design and computing which are either intentionally hidden or simplified by coding automation functionalities of authoring software. This interface provides dynamic and intuitive access to programming and multimedia resources. Learners learn

from their tentative trials on the combination of scripting, multimedia, parameters and attributes. The result of the design and coding can be discussed in a distributed environment, and the final coding can be saved and used in standalone basis for building up prospective system or presentational multimedia contents. The system is considered both a learning and production tool in the stream of design computing.

6. Conclusion

The goal of this research is to demonstrate the importance of multiple representations and scaffolding strategies in design computing education software development. This research is premised on the belief that stimulative design computing learning and teaching based on a multiple presentations and learner-centered design approach can lead to significant improvements in the effectiveness of design courses and to the future capabilities of practicing designers in architecture and the allied arts by means of digital multimedia and computing languages. This research is under progress.

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References

Bliss, J., Säljö, R. and Light, P (eds.): 1999, Learning Sites – Social and Technological Resources for Learning, Pergamon.

Boshuizen, H.P.A. and Schiff, H.J.M.: 1998, Problem solving with multiple representations by multiple and single agents: an analysis of the issues involved, in Van Someren, M. W., Reimann, P., Boshuizen, H.P.A. and De Jong, T. (ed.), Learning with Multiple Representations, Pergamon.

Dillenbourg, P. (ed.): 1998, Collaborative Learning: Cognitive and Computational Approaches, Pergamon.

Eastman, C., Newstetter, W. and McCracken, M. (eds.): 2001, Design Knowing and Learning: Cognition in Design Education, Elsevier.

Lucking, R.: 1999, Assisting child-computer collaboration in the zone of proximal development, in Bliss, J., Säljö, R. and Light, P (eds.), Learning Sites – Social and Technological Resources for Learning, Pergamon.

Lutz, M.: 1996, Programming Python, O'Reilly & Associates.

Markman, A.B.: 2000, British Journal of Educational Psychology, Vol.70 (1).

Myers, B., Hudson, S.E. and Pausch, R.: 2001, Past, Present, and Future of User Interface

Software Tools, in Carroll, J.M. (ed.), Human-Computer Interaction in the New Millennium, ACM.

Ousterhout, J.K.: 1991, An X11 toolkit based on the tcl language. Winter USENIX Technical Conference, 105-115.

Plomp, T. and Ely, D. P. (ed.): 1996, International Encyclopedia of Educational Technology.

Quintana, C., Carra, A., Krajcik, J. and Soloway, E.: 2001, Learner-Centered Design: Reflections and New Directions, in Carroll, J.M. (ed.), Human-Computer Interaction in the New Millennium, ACM.

Reifel, S. and Brown, M. H. (ed.): 2001, Early Education and Care, and Reconceptualizing Play. JAI.

Seel, N.M. and Dörr, G.: 1994, The supplantation of mental images through graphics: Instructional effects on spatial visualization skills of adults, in Schnotz, W. and Kulhavy, R. W. (eds.), Comprehension of Graphics, North-Holland.

Teitelman, W.: 1979, A display oriented programmer's assistant, International Journal of Man-Machine Studies, 11, 2, 157-187.

Tesler, L.: 1981, The Smalltalk environment, Byte Magazine, 6, 8, 90-147.

Van Someren, M. W., Reimann, P., Boshuizen, H.P.A. and De Jong, T. (ed.): 1998, Learning with Multiple Representations, Pergamon.

Wall, L., and Schwartz, R.L.: 1992, Programming perl. Sebastopol, CA: O'Reilly & Associates.

COGNITIVE BIASES AND PRECEDENT KNOWLEDGE IN HUMAN AND COMPUTER-AIDED DESIGN THINKING

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Abstract. Cognitive *biases* (illusions) and potential errors can occur when using precedent knowledge for analogical, pre-parametric and qualitative design thinking. This paper refers largely to part of a completed research (Bay 2001) on how heuristic *biases*, discussed by Tversky and Kahneman (1982) in cognitive psychology, can affect judgement and learning of *facts* from precedents in architectural design, made explicit using a kernel of conceptual system (Tzonis et. al., 1978) and a framework of architectural representation (Tzonis 1992). These are used here to consider how such illusions and errors may be transferred to computer aided design thinking.

1. Background

In the use of precedents as analogy for creative problem solving in design, implicit assumptions are often made about the success of precedents and the possible mapping over of the structure of *morphology*, *operation*, and *performance*[1] to new design problems in a new contexts. The selection of precedent knowledge for used in computer retrieval and reasoning systems are often based on human judgments and beliefs that these precedents are successful. Most judgements and descriptive statements of the success of historical and contemporary architectural examples are based on human heuristics rather than normative assessments because of the limitations of computational resources and time in practice.[2] As human heuristics can be

[1] Refer to Tzonis (1992) for more about representing architectural knowledge for analogical thinking creative thinking. The author here uses the concepts and relationships of *morphology*, *operation* and *performance* for discussion throughout this paper.
[2] Please refer to Bay (2001, 49-72) for more discussion on use of precedents, beliefs, judgement and decision-making in practice in the case of tropical architecture.

affected by associated cognitive *biases* (illusions)[3] that lead to systematic errors in design thinking (Bay 2001), knowledge contents in computer knowledge systems can also be saddled with in-built potentials for errors in application.[4]

For instance, in the use of traditional houses as precedent knowledge, assumptions are made for their success and applicability across context of past environment to present urban settings (Bay 2001, 46). Also in another example, in Fang (1993) the choice of using the prototype Beijing courtyard house as the precedent knowledge for a computer precedent analysis to facilitate design reasoning is based on the assumption and belief that the new courtyard house operates and performs well, and that the knowledge can be used as facts for computer learning. These beliefs are made with human heuristics with little or no recourse to normative computational methods of assessments, and may be subjected to cognitive biases (illusions).

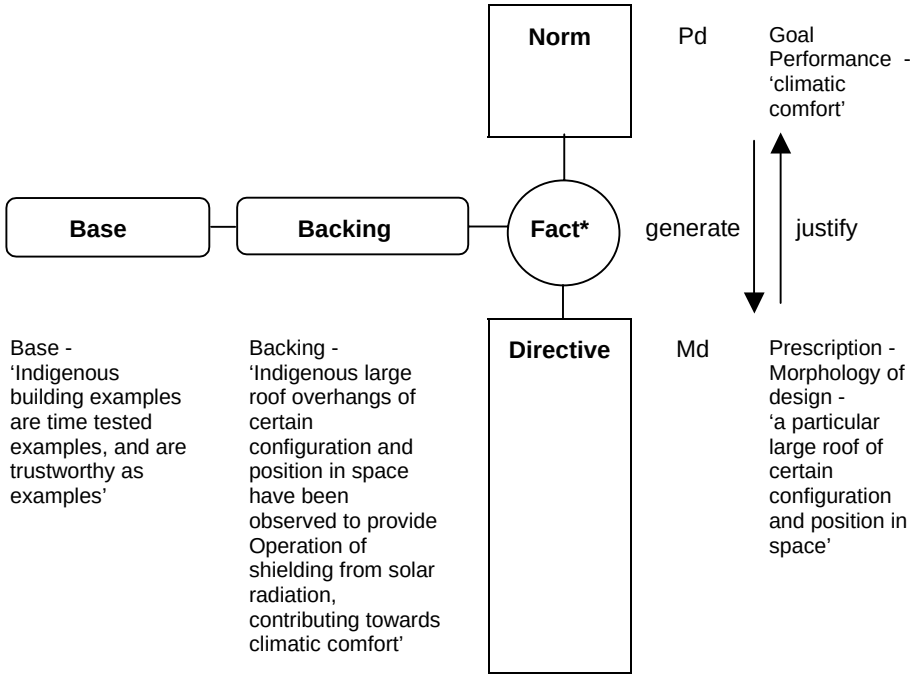
In computer precedent retrieval and reasoning systems, the human approach to using precedents for problem solving is emulated, and with it also the heuristic assumptions and beliefs in the precedent knowledge and application. As a result, the knowledge content and usage may be affected by heuristic biases that lead to errors, transferred from the human cognitive systems to the computer systems.

2. Human learning of dysfunctional facts

The actual internal design thinking process in the mind of the designer is not totally obvious, but can to a certain degree be described and understood with a model based on the external thinking process, observed through the descriptive and prescriptive (normative) statements made by the designer. A Kernel of Conceptual System represents a minimal necessary cognitive structure of argumentation based on the theory of action, and evaluation of action (Tzonis et al., 1978). This is used with a framework for representing architectural knowledge in analogical creative thinking (Tzonis 1992) to model an instance of design thinking in tropical architecture in Figure 1.

[3] Cognitive '*bias'* used here is in the sense referred to by Tversky and Kahneman (1982) and Osherson (1995) as 'illusion' related to certain heuristic used in thinking that leads to errors in judgement and decision making. This may not be confused with 'bias' (preference) in the sense that 'he has a bias for red', meaning 'he tends to prefer red emotionally or ideologically as a colour or style'. This does not mean that his 'tendency' or 'preference' cannot cause a heuristic *bias*; i.e. if this inclination influences a heuristic in use, a resulting heuristic *bias* can be linked to it.

[4] *Biases* are not the only reasons for incidences of design judgement errors. Errors can be attributed to many other factors, including poor education, low fees that limit search for solutions, outdated building codes and regulations, and insufficient details about precedents in reading materials. In a sense they are interrelated and there are overlaps in their effects on design thinking. This paper focuses on the effects of *biases.*



*** Fact** 'IF large roof overhang similar to precedent example, THEN shield solar radiation', THEN certain degree of protection, contributing towards climatic comfort',
Or,
'IF large roof overhang similar to precedent example, THEN certain degree of protection, contributing towards climatic comfort'

Figure 1. Kernel of Conceptual System; with an example for a roof morphology directive for a 'climatic comfort' norm, justified by a fact, learned from a backing and base

In the instance (Figure 1), the learning of the *fact* 'IF large roof overhang similar to precedent example, THEN…. certain *performance*', heuristics are used for judgement. One of these heuristics employs the mechanism of similarity (*representativeness* or match) of problem structure for reasoning. The association with success of the *backing* example is another heuristic used dependent on the *availability* of authority and trustworthiness of the example; i.e. the *base*. Systematically, a *norm* (goal) for a certain degree of goal *performance* (Pd) relating to this *fact* should generate a corresponding prescriptive *morphology* (Md) of a certain physical attribute, which when built should perform as expected. However, if there are cognitive *biases* due to *representativeness* and *availability*, they can cause unwarranted confidence of judgement in the *fact*. Since the decision for a certain prescribed *morphology* intended for implementation depends on the faulty

fact statement, then the actual *performance* may not be as desired when built.

For instance, the roof may look like it will work, but actually do not work well, but the *representativeness bias* creates the overconfidence in the judge to assess that it works well corresponding to the degree it is *representative* of success. Another instance, the roof does not work well, but because the example is well publicised, the *availability bias* creates overconfidence in the judge to think that it works well corresponding to the degree of fame or salience making it easier to imagine success. If any of these happens, the *fact* has an in-built error due to *bias*.

According to Rescher (1966) for Heterogeneous Command Inference, where command means *norms* here, "A command inference that infers a command conclusion from premises containing a mixture of commands and assertoric statements can be 'valid' only if the command conclusion must be terminated whenever (i.e., in any possible world in which) all the command premises are terminated and all of the assertoric premises are true". 'Assertoric premises' here refers to the descriptive *fact* statement, and it must be true for the *directive* to be 'valid'. If the desired *performance* (Pd) generates a corresponding desired *morphology* (Md), justified by a dysfunctional *fact* (belief or descriptive statement), then it is not 'valid'.

The cognitive *biases* related to *representativeness and availability*, are termed by Kahneman and Tversky (1982) as the '*illusion of validity*', and *biases due to imaginability* respectively, and can affect professionals in the financial, legal and clinical context. Cognitive experimentation (Bay 2001, 155-170) shows that subjects given photographs of precedent architectural projects can be overconfident in judging the *performance* of these examples because they looked like they will perform well but actually do not in reality. Also separately because they were projects by famous architects making it easier to imagine that they perform more than they actually can. Case study of design judgements by architects and writers (op. cit.) also shows that professional, successful and famous architects and writers can made mistakes related to *representativeness* and *availability biases*.

Many architectural publications of buildings carry descriptive statements of *performances* of buildings that are based on the writer's heuristic judgement. Judgement is usually made without normative quantitative calculation. The spatial quality assessments and predictions are done with the mind and senses[5], usually by comparing graphically and visually with past experience and precedents. There are possibilities of errors due to cognitive *biases* embedded in these selections of so-called 'good

[5] This includes surveying a building on site, commonly known as 'visual inspection' of conditions, as opposed to normative quantitative measurements with instruments and calculations.

precedents'[6], which can be problematic. This type of precedent knowledge in literature, with embedded errors, not only cause errors in human design thinking, but they can transfer the errors due to *biases* to other literature and computer knowledge systems that use them as knowledge base, and perpetuate the problem.

3. Computer-aided knowledge retrieval and machine learning of facts

The problem above is particularly applicable to the case of creative-associative knowledge retrieval systems, like the 'OASIS' (Tan et. al 2000), or other simpler visual collection information retrieval systems, where the knowledge input are judged in pre-parametric (Ulrich 1988) and qualitative (Kuipers 1994) modes, and usually with limited descriptive or belief statements about the *performances* and usually lack of statements about the *operations* of various *morphologies* in the visual information.

In the Architectural Precedent Analysis (ARPRAN) approach, Fang (1993) used the precedent knowledge based on literature that reported or claimed the success of *performance* and *operation* of the *morphology* of the new Beijing courtyard house, which were designed based on heuristic usage of precedent knowledge of older courtyard houses and the city. Fang assumed those *facts* were accurate, but the likelihood of errors due to *biases* could be there, and machine learning from this problem solving experience might be problematic.

Similar systems to precedent analysis are systems that employ example-based learning (Fang 1993, 116), which requires both similarity-based and explanation-based methods to learn from examples. A system developed by Kedar-Cabelli (1988) will be used here to discuss how cognitive *biases* can affect computer example-based learning within the structure of the system.

In the *Computational model of purpose-directed analogy* (Op. cit., 96-102), Kedar-Cabelli gave a case study of generalisation using the interaction of goal concept, operations and physical properties to explain a 'HOT-MUG' with a base ceramic mug and to justify a target styrofoam cup as a 'HOT-MUG', and in turn use this knowledge (*fact*) learned as a generalisation of a concept definition of a 'HOT-MUG'.[7] In the case, the plan of action leading to the main purpose 'enable INGEST hot-liquid', includes enabling operations, such as IF PUTIN, KEEP, GRASP, PICKUP, INGEST, THEN 'enable INGEST hot-liquid'. These enabling operations are in turn connected to preconditions, IF 'can (be-grasped-by agent, hot-liquid),

[6] 'Good precedents' here includes examples and related rules, and even typology in a general sense that is belief to be adequate and suitable to guide design in new problems.

[7] In a sense, there is similarity to argumentation in the Kernel of Conceptual System where the backing example provides concept structure and learning of a *fact*, and generalisation.

IF structural features, IF 'insulate-heat grasping-area', and attribute, IF 'material (ceramic) has-part (handle)'.

Relating to arguments above in this paper, these are interrelated descriptive or belief statements, which are input or supplied by the system developer (human). The IF-THEN statements relate these elements together as if belief statements or *facts.* Could these be subjected to possible heuristic *biases*? In the generalisation there is a statement derived from the target and the explanation in the base, which goes like this: 'IF styrofoam, insulate-heat, grasping-area, THEN can be grasped by agent, THEN enable INGEST hot-liquid'. It is believed that the conical shape of the styrofoam material has a 'grasping-area' therefore it is graspable. However, if the styrofoam is too thin, but the conical shape looked like graspable, then the *fact* "IF styrofoam, conical, THEN graspable-area, THEN etc' could suffer a *bias* of *representativeness* transferred from the human supplier of related descriptions. If such an error happens, then it becomes embedded in the knowledge system.

Can the human supplier of related descriptions for the computer be aware that he is suffering a *bias* without external prompting? If he knows that he may suffer from *biases*, can that knowledge itself help eliminate the problem? According to Arkes (1986, 587), "One technique that has proven to be absolutely worthless is telling people what a particular *bias* is and then telling them not to be influenced by it". This is because the subjects do not actually know how to overcome these *biaes* even if they know they may exist and affect them. Bay (2001, 168) also showed that the warning about the existence of both *representativeness* and *availability biases* was no help in *debiasing* in the case of design thinking in tropical architecture.

4. Therapeutic mechanism and possible applications

For *debiasing* in human design thinking, Bay (Op. cit.) tested and showed that the introduction of *rebuttal* to increase *availability* of thoughts of opposite outcomes can refocus the attention of the mind making judgement, and can improve accuracy of judgement subjected to *illusion of validity* and *biases due to imaginability*.

Possible application could be to increase the *availability* of design knowledge of buildings where they do not work; to put 'how and why' they do not work alongside information that they work, and with the varying degrees of success assessed with normative methods. This can possibly serve as the *rebuttal-debiasing* mechanism for the human precedent user to reduce errors because of embedded *biases* in *facts* (or concept definition for purpose-directed analogy). This could also help in improving the selection of more accurate precedents for computer knowledge retrieval systems and for

machine learning. Fang (1993, 108), referring to Carbonell (1983), noted that similarity-based learning can be classified as learning from only positive examples and learning from both positive and negative examples, where learning from positive examples only do not provide information for preventing over-generalisation of the inferred concept. He asserted that over-generalisation for learning from only positive examples might be avoided by considering only the minimal necessary generalisation, or by relying upon a prior domain knowledge to constrain the concept to be inferred. Carbonell (1995, 591) also noted that analytic systems utilise "past problem solving experience (the exemplars) to guide which deductive chains to perform when solving new problems", thus increasing efficiency without sacrificing accuracy and generality. However, as argued above, the prior knowledge and the exemplars itself may be flawed with transferred and embedded *biases* and potential errors. As for providing both positive and negative examples for inductive computer learning to prevent over-generalisation, this can be considered for improving accuracy of machine learning, provided some normative checks are made to ensure positive examples are truly positive and negative examples are truly negative, and not just look like they are negative but actually works. Several analytic systems that allow learning from successes and failures (Op. cit. 589-591) could similarly be considered for improving machine learning accuracy and limit the problem of possible embedded errors due to *biases*.

5. Conclusion

Human beings use heuristics to quickly solve complex problems. However, cognitive *biases,* associated with heuristics, can affect human design thinking in practice, with possible systematic errors. Errors due to *biases* can be transferred through precedent knowledge and *facts* in computer-aid retrieval and machine learning systems, and become embedded errors.

Carbonell (Op. cit. 589, 594) noted new systems that explore the possibility of inaccurately labeled and unlabeled instances for the inductive machine learning, and the possibility of combining inductive and analytic systems. To what extent can these systems prevent or reduce possible transferred errors due to *biases*? This is an interesting area to explore, as computers continue to be more human-like in heuristics.

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References

Arkes, Hal R.: 1986. Impediments to accurate clinical judgment and possible ways to minimize their impact, in Arkes, Hal R., and K. Hammond, (eds), Judgment and decision making, Cambridge University Press, USA, pp. 582-592.

Bay, Joo-Hwa: 2001. Cognitive biases in design: The case of tropical architecture. The Design Knowledge System Research Centre, Faculteit Bouwkunde, Technische Universiteit Delft, The Netherlands.

Carbonell, J. G.: 1983. Derivational analogy and its role in problem solving, in, Proceedings AAAI-83, Washington, D.C., pp. 45-48.

Carbonell, J. G.: 1995. Paradigms for machine learning, in Luger, G. F. (ed.), Computation & Intelligence: Collected readings, AAAI Press, The MIT Press, pp. 587-595.

Fang, Nan: 1993. A knowledge-based computational approach to architectural precedent analysis. Publikatieburo Boukunde, Technische Universiteit Delft, The Netherlands.

Kedar-Cabelli, S.: 1988. Toward a computational model of purpose-directed analogy, in Armand Prieditis (ed.), Analogica, Morgan Kaufmann Publishers, Inc, California; Pitman, London, pp. 89-107.

Kuipers, Benjamin: 1994. Qualitative reasoning: Modelling and simulation with incomplete knowledge. MIT Press, Cambridge, Mass.

Osherson, Daniel. N.: 1995. Judgment, in E. E. Smith, and Daniel N. Osherson (eds), Thinking, Invitation to cognitive science, Vol. 3, MIT Press, Cambridge, MA, pp. 55-87.

Rescher, Nicholas: 1966. The logic of commands. Routledge and Kegan Paul, London.

Tan, M., B. K. Tan, and J. Ngatemin: 2000. By rhyme or reason: Rapid design thinking by digital cross referencing, in B. K. Tan, M. Tan, and Y. C. Wong (eds), Proceedings of the fifth conference on computer aided architectural design research in Asia: CAADRIA 2000, published by CASA, National University of Singapore, pp. 399-410.

Tversky, A., and D. Kahneman: 1982. Judgment under uncertainty: Heuristics and biases, in D. Kahneman, P. Slovic, and A. Tversky (eds), Judgment under uncertainty: heuristics and biases, Cambridge University Press, Cambridge, UK, pp. 3-22.

Tzonis, Alexander: 1992. Huts, ships, and bottlenecks: Design by analogy for architects and/or machines, in Nigel Cross, Kees Dorst, and Norbert Roosenburg (eds), Research in design thinking, TUDelft, Delft, pp. 130-165.

Tzonis, A., R. Berwick and M. Freeman: 1978. Discourse analysis and the logic of design, in Alexander C. Tzonis (ed.), Conceptual systems in design: Two papers, Harvard Graduate School of Design Publication Series in Architecture, A: 7817.

Ulrich, Karl T: 1988. Computation and pre-parametric design, Technical report of MIT Artificial Intelligence Laboratory. AL-TR 1043.

INTERDISCIPLINARITY: PERCEPTIONS OF THE VALUE OF COMPUTER SUPPORTED COLLABORATIVE WORK IN DESIGN FOR THE BUILT ENVIRONMENT

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Abstract. This paper presents the findings from a study into the current exploitation of CSCW in design for the built environment in the UK. The research is based on responses to a web-based questionnaire. Members of various professions including civil engineers, architects, building services engineers and quantity surveyors were invited to complete the questionnaire. The responses reveal important trends in the breadth and size of project teams at the same time as new pressures are emerging regarding team integration and efficiency. The findings suggest that while CSCW systems may improve project management (e.g. via project documentation) and the exchange of information between team members it has yet to significantly support those activities that characterize integrated collaborative working between disparate specialists. The authors conclude by combining the findings with a wider discussion of the application of CSCW to design activity – appealing for CSCW to go beyond multidisciplinary working to achieve interdisciplinary working.

1. Introduction

Design for the built environment is probably the most multidisciplinary practice in all of the design professions. Now, more than ever before, architects, civil engineers, building services engineers, quantity surveyors, construction managers, landscape architects and interior architects are required to work with a very high level of integration during the design and development of schemes. It was clear from informal discussions with practitioners at the outset of the research that, to a greater or lesser extent, the various professions are experiencing a number of pressures. There are pressures to reduce lead-time, to reduce costs, to reduce defects, to lower environmental impact and to increase client satisfaction. Also there are

pressures to improve communication with colleagues, and to establish consistency in tools and procedures. Simultaneously there are pressures to adopt computer-based working - partly so as to address the above issues. The cumulative result of these pressures has been that today many professionals in this broad field display some participation in computer supported collaborative working (CSCW). It was also clear from these early discussions that CSCW did not seem to be achieving the influence that it promised. Opinion suggested that while the individual constituent parts, the team members, exchanged information, their working did not display a sophisticated level of integration. It seemed to be more 'multidisciplinary' working and less 'interdisciplinary' working. Consequently, it was proposed to undertake a modest questionnaire survey that would hopefully illuminate this phenomenon and which might provide particular foci for future research.

2. Research Design

In December 2001 a questionnaire was devised, piloted and developed. It was designed to be completed in under ten minutes and presented three sections. Section One sought information about respondents' current activities. Sections Two and Three sought opinion on team working and CSCW respectively and exploited the strategy of offering statements to which respondents could state their level of agreement or disagreement via four check boxes. For example:

My work involves multidisciplinary team working
Totally agree 0 0 0 0 Totally disagree.

The use of only four categories was deliberately used to prevent respondents 'sitting on the fence'- forcing them into partial agreement or disagreement. As a research strategy it has its advantages and disadvantages. It was anticipated that respondents might overly use the second and third categories due to an unwillingness to present the strong 'total' feelings specified by the first and fourth categories. However, the feedback did not confirm this worry. The questionnaire also included six expandable boxes allowing potential respondents to add information that could inform the research. A database was compiled consisting of email addresses of people who were known to be active in one or more fields associated with design for the built environment (architects, building services engineers, civil engineers, construction managers plus a small number of other specialist professionals). The questionnaire was uploaded to the project website: http://tyne.open.ac.uk/~pm2976/cscw_survey_1.html

and in January 2002 150 invitations were emailed out. Potential respondents were invited to return the completed questionnaires electronically by a given deadline. By the time of the deadline 25 had replied. The low response is disappointing but it provides an indication of trends in this field. Given the low response an overly statistical approach to the presentation of the data would not be appropriate. What trends there are emerge easily from simple presentations of the data. Bar charts would have been ideal for this presentation but space did not permit. If the responses increase it may be relevant to look more closely at the data, perhaps looking at responses within particular professions. In the following section, where percentages are given, the figure is followed by the actual number of returns

3. Research Findings and Discussion

3.1 SECTION ONE

Of the 25 respondents, 11 were building services engineers, 6 were civil engineers, 4 were project managers and 2 were architects. The remaining two respondents were a landscape architect and a Director of a professional institution. The respondents would appear to be very experienced in their professions, 52%(13) stated they had more than 20 years experience in their work, 36%(9) stated they had 10-19 years experience.

Question 3 asked *'What do you use your computer(s) for?'* and offered 9 fields plus an expandable box for 'other' uses to be specified. Not unexpectedly, respondents demonstrated multipurpose use of their computers with a mean of 4.4 uses per respondent. Most popular uses were management 84%(21), communication 84%(21), document control 72%(18), researching 44%(11), detail design 40%(10), specifying 36%(9) and conceptual design 28%(7). The 'other' category revealed a number of tasks of personal relevance to the individual respondents. They concerned, for example, financial modelling, safety assessment, feasibility, sales and marketing but none of these received more than 2 mentions and are therefore not viewed as significant at this stage.

Question 4 asked *'Which forms of output are you producing from the above tasks?'* and the findings confirm the multipurpose use found above (a mean of 4.5 forms of output per respondent). The most common outputs were word processing 96%(24), spreadsheets 92%(23), administration 80%(20), databases 52%(13), drawings including animations 40%(10), CAD models 28%(7) and bills of quantities 20%(5). The 'other' category produced 8 other headings e.g. Web publishing, presentations, sales output, and Gantt charts but no heading received more than one mention.

Question 5 asked for an estimate of the percentage of working time spent at a computer and offered 5 alternatives (100%, 75%, 50%, 25% and 0). 32%(8) spent ¼ of their working time at a computer, a further 32%(8) spent ½ of their time at a computer, 28%(7) spent at least ¾ of their working week in front of a computer and for two people (8%) all of their time was computer based.

3.2 SECTION TWO

From question 6 onwards the survey moves away from requesting descriptive data and begins to require respondents to make judgements regarding their multidisciplinary team working. It also marks a shift in question design. From question 6 onwards the respondents are confronted with statements with which they are asked to rate their level of agreement. Question 6 through to the penultimate question (Q26) was presented in this way - as a statement against which respondents had to indicate one of four levels of agreement/disagreement.

Question 6 through to question 14 was seeking to establish a foundation of current practice within which the emergence of computer supported collaborative working could be investigated. This section was titled 'Team working, multidisciplinary working and your experience of changes over the past two years'. Question 6 stated directly *'My work involves multidisciplinary team working'.* 64%(16) totally agreed, 28%(7) partially agreed and 8%(2) partially disagreed. The follow-up statement said *'I am involved in <u>more</u> multidisciplinary working than I was two years ago'.* 24%(6) totally agreed, 44%(11) partially agreed, 16%(4) partially disagreed and 16%(4) totally disagreed. Given the consistency of the questionnaire design the remaining data from each statement will be provided simply as four percentages with the actual number of respondents given in brackets. In each case the first percentage relates to 'totally agree' and the fourth percentage relates to 'totally disagree'.

Q8 *'The number of different disciplines represented in teams in which I work has increased in recent years'.*

16%(4); 60%(15); 8%(2); 12%(3) including one non-response.

Q9 *'I now send, receive or exchange more information with colleagues from other disciplines'.*

32%(8); 52%(13); 12%(3); 0% including one non-response.

Q10 *'There is an increased requirement for me to make sense of, or interpret information from other disciplines'.*

24%(6); 52%(13); 12%(3); 8%(2) including one non-response.

Q11 *'There is an increased requirement for me to make decisions regarding other disciplines'.*

8%(2); 44%(11); 36%(9); 8%(2) including one non-response.

Q12 *'There is an increased requirement for me to integrate closely with other team members'.*

40%(10); 48%(12); 4%(1); 4%(1) including one non-response.

Q13 *'There is an increased requirement to improve the team efficiency'.*

44%(11); 44%(11); 4%(1); 4%(1) including one non-response.

Q14 *'There is an increased requirement to improve team output quality'.*

60%(15); 32%(8); 4%(1); 4%(1).

Section Two of the survey confirms what many will know to be true from their own experiences – that team working is increasing and there are very real pressures to increase team efficiency and team output quality. The findings also confirm that in this field of design for the built environment teams now involve a wider range of specialists and communication between these specialists has increased. However, traditional lines of demarcation between specialist areas or professions still seem to exist. The responses are less supportive of the notion that this increased team working has lead to new responsibilities for interpreting or making decisions based on data arising from outside their area of specialism.

3.3 SECTION THREE

Section Three of the questionnaire sought to explore respondents opinions regarding their computer supported collaborative working. Given the increasing pressures towards team working it was important to begin to establish how CSCW was contributing to a strategy for addressing this pressure. Questions 15 to 26 use the same format as those in Section Two.

Q15 *'More of my team working is via computer supported collaborative working'*.

36%(9); 36%(9); 16%(4); 12%(3).

Q16 *'CSCW has improved communication in the teams with which I have worked'.*

28%(7); 44%(11); 12%(3); 12%(3) including one non-response.

Q17 *'CSCW has improved creativity in the teams with which I have worked'.*

8%(2); 24%(6); 44%(11); 20%(5) including one non-response.

Q18 *'CSCW has improved problem-solving in the teams with which I have worked'.*

4%(1); 36%(9); 40%(10); 16%(4) including one non-response.

Q19 *'CSCW has improved project management in the teams with which I have worked'.*
16%(4); 36%(9); 32%(8); 8%(2) including two non-responses.
Q20 *'CSCW has improved project documentation in the teams with which I have worked'.*
28%(7); 52%(13); 8%(2); 4%(1) including two non-responses.
Q21 *'CSCW has increased the quantity of work I get through'.*
16%(4); 52%(13); 20%(5); 4%(1) including two non-responses.
Q22 *'CSCW has increased the quality of my contribution to projects'.*
12%(3); 60%(15); 16%(4); 4%(1) including two non-responses.
Q23 *'CSCW has increased the overall quality of output from teams with which I have been associated'.*
20%(5); 56%(14); 12%(3); 4%(1) including two non-responses.
Q24 *'CSCW has increased my satisfaction with outcomes of projects'.*
4%(1); 48%(12); 36%(9); 0% including three non-responses.
Q25 *'CSCW has increased client satisfaction with outcomes of projects'.*
4%(1); 52%(13); 28%(7); 4%(1) including three non-responses.
Q26 *'CSCW has increased understanding between team members'.*
12%(3); 52%(13); 28%(7); 0% including two non-responses.

The responses to Section Three do not provide the strength of feelings that Section Two reveals. Also there were more non-responses to questions. The non-responses in Section Three involved the same three people but this group was different to those offering non-responses in Section Two.

Clearly the increase in team working identified in Section Two is translated into an increase in CSCW. 72%(18) of respondents totally or partially agreed that more of their team working over the past two years has been computer supported. Interestingly, 68%(17) totally or partially agreed with the statement that CSCW has increased the quantity of work they get through. Questions 16 to 20 focused on qualitative improvements as a result of CSCW. 72%(18) believed that communication had improved and similarly that project documentation and project management had improved with 80%(20) and 52%(13) respectively in total or partial agreement with the statement. Interestingly 64%(16) disagreed that team creativity had been improved with 56%(14) disagreeing that team problem solving has improved with CSCW. More significant are the responses to questions 22 and 23. 72%(18) of respondents totally or partially agreed with the statement *'CSCW has increased the quality of my contribution to projects'* while 76%(19) totally or partially agreed with the statement *'CSCW has increased the overall quality of output from teams with which I have been associated'.* The increase in self-satisfaction is marginal but belief that there has been an increase in client satisfaction as a result of CSCW is more marked. The purpose of question 26 was to see whether any increase in communication

was matched by a perceived increase in understanding between team members. This would seem to be the case.

4. Conclusion

As noted above, a 16% return rate to the questionnaire was disappointing. Furthermore, given that 11 of the 25 respondents were building services engineers the findings may be viewed as distorted by the particular activities or requirements of this group. The poor return may be to do with questionnaire design, pressure of work or insufficient incentive. It may also indicate that individuals feel they have nothing to offer such a study, perhaps because their use of computers for collaborative work is small or considered inexpert. However, those that have replied reveal themselves to be aware of and perhaps interested in CSCW and maybe even open to further studies of their CSCW.

The study set out to identify trends in CSCW. This experienced group of practitioners clearly consider themselves to be involved in multidisciplinary team working and they indicate that this has increased in the last two years with a simultaneous increase in the number of different disciplines represented in the teams with which they have been associated. The responses reveal the existence of pressures to achieve close integration between team members, to achieve greater efficiency and to improve the quality of the output of the team. A change in responses seemed to emerge when these pressures were addressed within the context of CSCW. While computer supported team working has increased for the respondents this seems to have manifested itself as an increase in communication without necessarily any increase in the quality of team working. When it was proposed that creativity and problem-solving have been improved by CSCW the responses indicate disagreement. At the same time project documentation and project management is believed to have been improved by CSCW.

CSCW seems to have increased the quantity of the work that the respondents get through but the rating for personal satisfaction is only marginal. Perhaps more importantly, there is a belief that CSCW has increased the quality of the respondent's contribution to projects and the overall quality of output from teams with which they have been associated. Future studies may seek to investigate whether this is a consequence of successful remote team working or due simply to computer based working with its access to computer based resources and tools. Either way, the outputs seem to have increased client satisfaction.

For these respondents CSCW has made contributions to supporting multidisciplinary group activity but potentially it can do much more.

Effective team working in design displays interchange between participants but this largely concerns the conveying of information. Design particularly requires the explicit intervention of participants whose expertise is to synthesize information and render it useable by the group. The goal for CSCW in design might be to support higher levels of 'interdisciplinary' collaborative working where participants are empowered to explore and negotiate meaning and generate conjecture. The notion of interdisciplinary in CSCW is not new (see Bannon, 1992) but its importance has re-emerged as a result of the volume of design activity taking place by distributed participants and the particular nature of designing. Kvan (1999), for example, proposed that supporting expert design behavior via CSCW tools required a perception of design activity as more than social and situated acts. Nissani (1997) has proposed that interdisciplinary working is essential where there is a need for creativity and where there exists complex problems. Multidisciplinary working is rich in information; interdisciplinary working is also rich in interpretation and transformation. It represents greater synergistic activity and it comes closer to offering the 'shared understanding' between participants as referred to by other CSCW researchers (see for example Maher, Simoff & Cicognani, 1999). Edmonds & Candy (1999) have noted the significant influence that computer based media have on creative thinking and particularly the emergence of ideas but there is still much research to do on the potential for CSCW to support and improve creative interdisciplinary working.

The exploitation of CSCW in design for the built environment and its influence in improving interdisciplinary working has been erratic but potentially design for the built environment can provide the ideal context for valuable developments to our understanding of both design and CSCW.

References

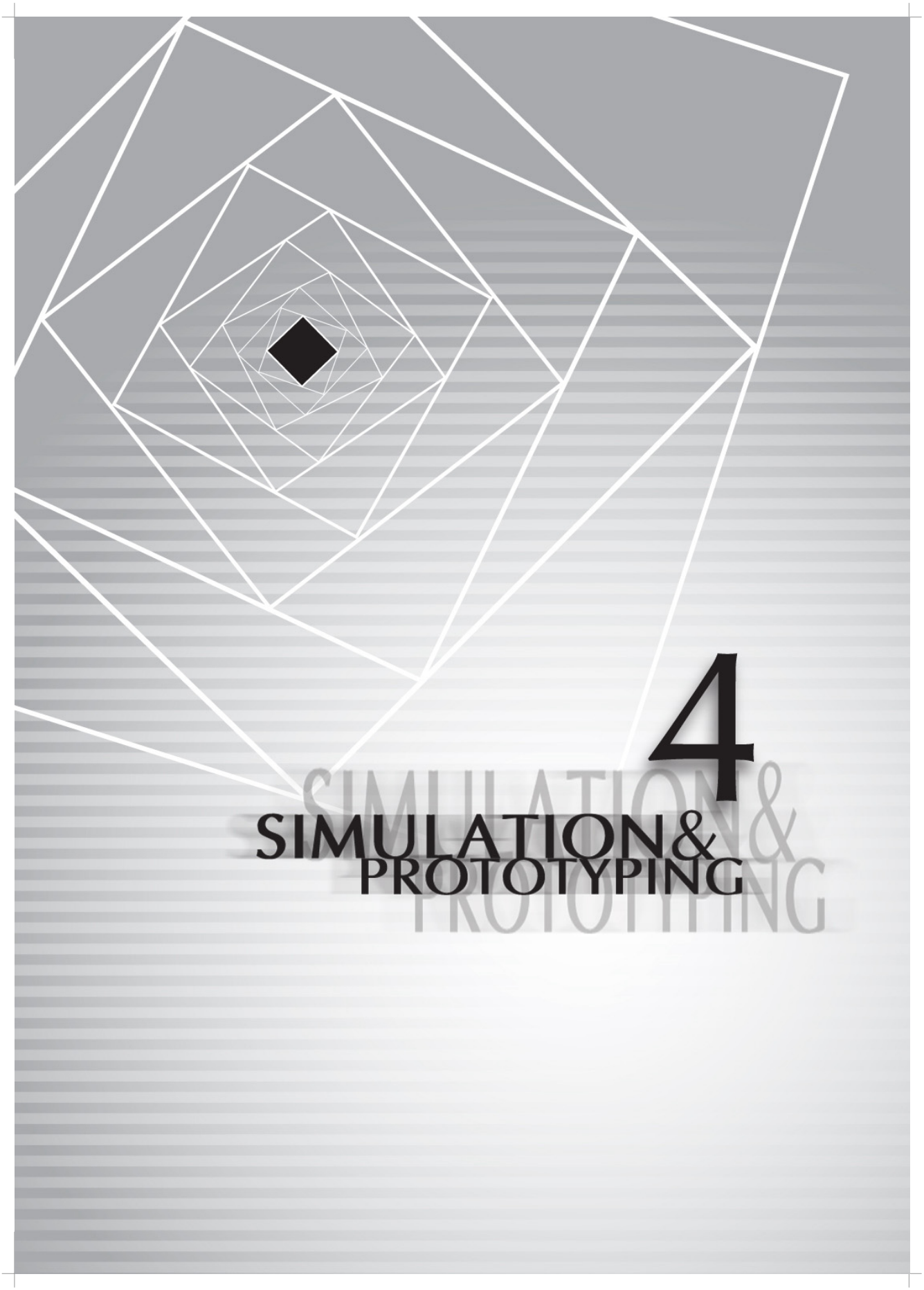
Bannon, L.: 1992, Interdisciplinarity or Interdisciplinary Theory in CSCW? Workshop paper for CSCW'92, October, Toronto, Canada.

Edmonds, E.A. & Candy, L.: 1999, Computation, Interaction and Imagination: Into Virtual Space and Back to Reality, in J. Gero and M-L Maher (eds), Proceedings 4th International Roundtable Conference on Computational Models of Creative Design. December, pp19-31.

Kvan, T.: 1999, Designing Together Apart, PhD thesis, Technology, Open University, UK.

Maher, M-L. Simoff, J. & Cicognani, A.: 1999, Understanding Virtual Design Studios, Springer, London.

Nissani, M.: 1997, Ten Cheers for Interdisciplinarity: The Case for Interdisciplinary Knowledge and Research, Social Science Journal 34(2), pp201-216.



4

SIMULATION& PROTOTYPING

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Simulation & Prototyping

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RAPID PROTOTYPING AND MULTIMEDIA DESIGN AT MMU

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Abstract. Although there have been reports worldwide where RP technology have been used outside the realms of the manufacturing sector, it is yet to be recorded, especially in South-East Asia, where RP technology is used in conjunction and to be integrated with multimedia design and content development. This paper will look at the integration of RP technology towards multimedia design at the Faculty of Creative Multimedia. This is especially fascinating where RP technology is used in a multi-disciplinary field as that of multimedia design for both academia and practice.

1. Introduction

Rapid prototyping (RP) technology has come a long way since the early inception of stereo-lithography (SL) in 1987 by the US-based company, 3D Systems Corp. Applications of such technology and its processes (Jacobs 1995; Horton & Radcliffe 1995) then only involved building mechanical part designs using liquid polymer as its build material. Nevertheless, early RP systems and its development have been implemented and used widely across the manufacturing sector. In addition, its application also contributed positively towards conceptualizing new product ideas and designs, and for creating mock-ups (Boon 1992).

There are indications of RP being integrated within a more creative, computer-aided design and manufacture (CADCAM) setting (Chiu *et. al.* 2001), but there is yet a note on it's integration towards multimedia

production design. As such, this paper will attempt to highlight the way in which RP is applied and integrated in the training and practice of multimedia design at the Faculty of Creative Multimedia (FCM), Multimedia University (MMU) Malaysia.

2. Towards Design and the MSC

Since the launch of the Multimedia Super-Corridor (MSC) in Malaysia, MMU is aimed to provide knowledge workers, expertise and research and development in areas related to multimedia, engineering, management and information and communication technology (ICT). On the whole, the MSC is poised to provide a high-tech infrastructure and environment, and to operate as a platform and catalyst for *Vision 2020* to be accomplished (Mohamad 1998). Hence, knowledge workers in areas providing and creating digital content and information design are critical to ensure the depth, breadth and innovative information towards multimedia design.

As multimedia design is fairly young with the Malaysian industry, its design and production processes have been, and is still on an exploratory basis. Although there has been a boom of *cyber-cafes* across the nation, online content and digital animation all seems too easy to apprehend at first sight by many locals. However, the required paradigm shifts in many aspects related to the success of the MSC on the whole needs greater knowledge and further insights than just being intrigued by the latest Flash technology [1] or digital special effects (SFX) used in movies.

As most academic institutions offering multimedia-based, content creation training is biased towards Information Technology (IT), the Faculty of Creative Multimedia at MMU is taking a different lead. The curriculum and direction of the faculty is design-based, and production-led (Khong 2001). As the faculty was established at the time when the nation was awakening to IT and the MSC, many local multimedia industries used MMU as a benchmark for best practice.

Nonetheless, like most design-based practice, be it a service or consumer industry, users and markets are invariably *human*. However, as multimedia design is a new concept and practice in the local context, there is not a specific design process that is adopted, but rather the process is an exploratory event both in academia and industry. Hence, there are many local adaptations of design and project management methods and techniques to suit the new digital medium of expression for *human* use and entertainment.

[1] Flash technology here refers to products developed by Macromedia Flash™, a trademark of Macromedia Inc.

3. Multimedia Design at FCM

The term 'multimedia' has various meanings and expectations. For instance, the transfer of text-based data with added hyperlinks, motion graphics and audio onto a digital medium might constitute a simple production of a multimedia product. Although this is a very simplistic example, a multimedia product is expected to amalgamate textual data, audio or sound, video, graphics and animation.

There are four multimedia-based groups sharing the multimedia design process practiced and disseminated at FCM. They are :

1) digital media (compact disk (CD) medium),
2) film and animation (3-D animation),
3) media innovation (print and Internet medium), and
4) interface design (product-based).

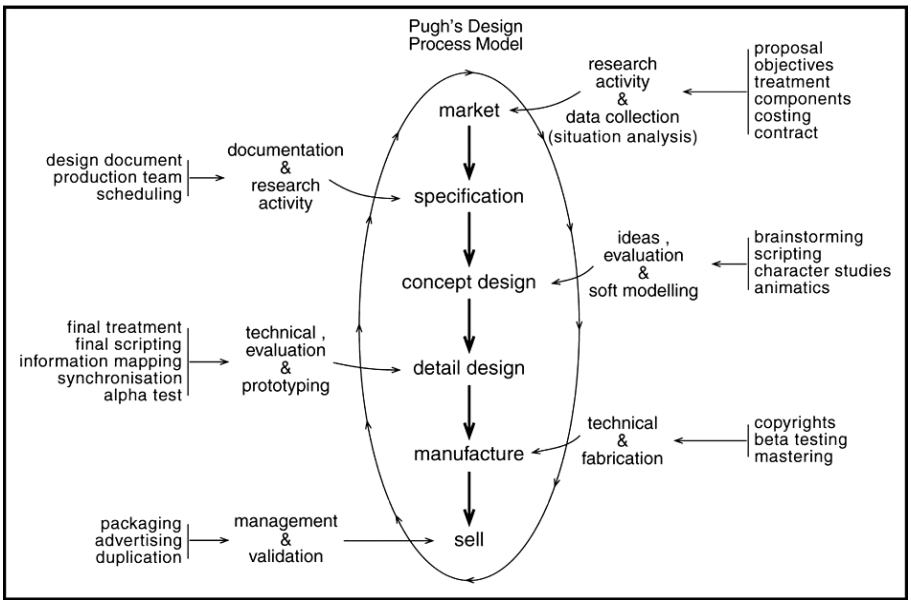


Figure 1. Multimedia design components against Pugh's design process model.

There are many references highlighting generic models of the multimedia design processes, both in practice and academia (MacMillan 1990; Olsen 1997), where related industries and organizations each practice their respective styles and interpretation of the process. However, for all intended purposes, a more generic design process model will be used in this paper as described by Pugh (1991) for ease of reference. As Pugh's model depicts an engineering design perspective towards the design process, Figure 1 highlights Pugh's design process together with related multimedia

components as practiced and disseminated at FCM. Certain specialized treatment (which varies from one production to another) and methods used in the multimedia production process are also included in figure.

4. RP and Multimedia Design

The use of rapid prototyping in the design industry has been widely highlighted and researched, e.g. its role and function in the design of consumer products (Evans 1997) and manufacturing (Chua & Leong 2000). However, RP technology is still not widely accepted and used in the local manufacturing context, let alone in the design process. On the other hand, RP can provide useful human factors information during the conventional product design process (Khong 2000), but its application has not been explored in the area of multimedia design.

With reference to Figure 1, RP technology is currently adopted by FCM in the stages of :

1) character studies – studying character pose and stance,
2) animatics – aiding cinematography and composition,
3) scripting – aiding visual scripting and storyboarding,
4) brainstorming – aiding computer simulations,
5) final treatment/scripting – physical reference,
6) alpha/beta testing – on/off-stage comparative model,
7) packaging – physical, visual reference,
8) advertising – physical negatives for production of models for gifts/sale.

The purpose of RP technology in multimedia design process is found useful when considering :

1) visual communication,
2) anthropomorphic evaluations,
3) alternative concepts,
4) visualising character composition, and
5) relative body-size evaluations.

The idea of visual and physical models in production design has a long history since the making of cartoon characters (Canemaker 1999) and SFX in films. This paper does not intend to address RP as a technology capable of replacing skilled expertise in model making for production purposes, but rather as a convenient avenue for producing quick references in this new multimedia-based domain. However, the advancement of IT and RP technology have made certain design situations where once complex and over-hanging parts were tedious to model, replicate and build, are now easily produced at an affordable price.

An example of a quick and mobile *3D printer* is the US-based, Z-Corp's

range of RP equipment. As the production of ideas and concepts move from the traditional, paper-based medium towards a digital environment, design concepts can be easily and cheaply produced by RP technology. As an example highlighting a portion of the multimedia design process involving RP technology, Figure 2A shows the development of an animated character's *head* using Alias|Wavefront Maya™ software, and its transfer to an RP machine, Z-Corp.'s Z402™ 3D printer (Fig. 2B) for immediate building of the part (Fig. 2C). The process involved part processing on the same workstation following the conventional method of document printing for the RP building – also including conventional *print queue* and *page setup* formats. This allows flexibility, is user-friendly and greatly improves efficiency to the production process.

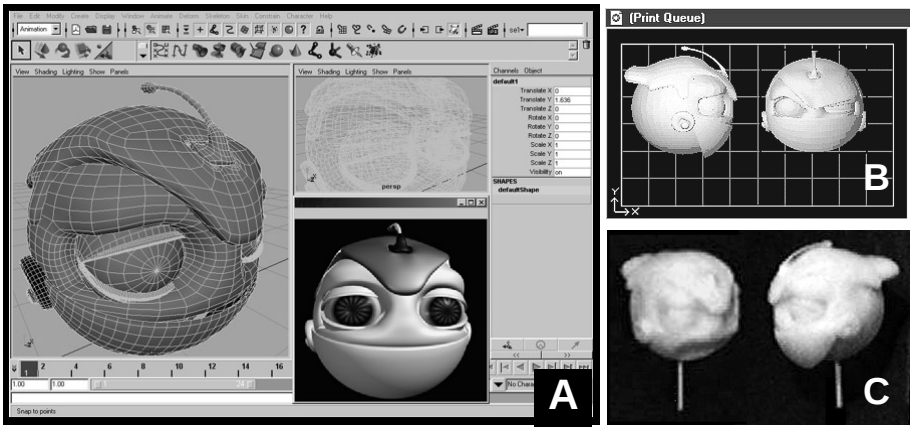


Figure 2. Development of an animated character (**A**); two components ready to build on RP (**B**); two components built using an RP machine (**C**) (courtesy of Faculty of Creative Multimedia, Multimedia University, Malaysia).

5. Integrated R&D at FCM

The training programmes at MMU share an integrated learning resource as multimedia design is considered a collaborative design (co-design) discipline. Hence, research and development (R&D) centers are also integrated in nature, where existing projects have shared interests.

The use of RP technology as an aid towards human factors and design issues in the multimedia design process is better enhanced when combined with other tools and techniques. Figure 3 shows the network of R&D setup

at FCM, comprising of four related interests of motion capture, RP, human-computer interaction (HCI) and virtual reality. These research-based interests are aimed at providing R&D opportunities in respective areas of multimedia design. However, the same setup of facilities can also provide opportunities for studies into design interactions and simulation within multimedia design.

For example, studying and mapping possible character movement using the motion capture facility can enhance design concepts in character animation for a digital game design. The completed character proposal can then be transferred to the RP laboratory for immediate parts building, while usability studies on HCI can be conducted on the proposed games console and its controls (if required, parts of the console design can be *printed* for physical prototype evaluations). Alternatively, the game design can be simulated in a virtual environment.

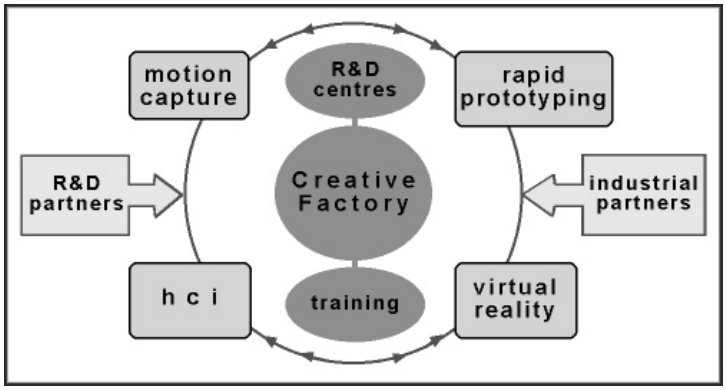


Figure 3. Schematic of FCM with its four related interests supported by research and industrial partners.

6. Conclusion

At present, MMU is the only organization in the country that provides an integrated set of laboratories and facilities for multimedia design R&D purposes. In addition, it is the first organization to house an RP facility within the MSC for the purpose of multimedia design and content development.

As the nation is awakening to multimedia design and the World Wide Web (WWW), it has to be said that the local multimedia industry lacks the R&D and production experience in designing and authoring CD-ROMs and

software for training purposes. Hence, local approaches to designing such products are, at present, exploratory and do not conform to specific methodologies and standards. However, the explicit use of certain tools and techniques to aid in the multimedia design process and its production is evident.

Whether producing an animated digital host, the architecture of an online shopping outlet, concepts for a hand-held personal digital assistant (PDA) or even an animated character for film, RP technology is ideal for producing rapid visual representations and physical references for multimedia designers.

Issues pertaining to the role of RP in multimedia, and its rationale as a human factors aid have been observed as being much more explicit compared to the design process itself. The use of RP technology as a means of addressing human factor's issues during the multimedia design process will also have implications towards the design of virtual environment.

This paper highlighted the use of RP within the multimedia production contexts, and has attempted to portray the current training and practice setting at FCM. On the whole, the RP technology implemented is towards its usage for design production purposes.

Currently, many local companies and the manufacturing sector are shying away from RP technology mainly because of its cost and maintenance factors. However, as RP technology is poised to improve with the advancement of materials technology and IT technology, issues on costing and the ease of producing parts will hopefully diminish in years to come.

Acknowledgements

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References

Boon, L.H.; et.al. (1992) Using computer-based tools and technology to improve jewellery design and manufacturing. *International Journal of Computer Applications Technology*. v5, 1; 72-80.

Canemaker, J (1999). Paper dreams: the art and artists of Disney storyboards. Hyperion, New York.

Chiu, ML; Lin, YM; Lee, CH; Tsai, PH (2001). Teaching rapid prototyping in CAD studios for creative design, in Gero, J; Chase, S; Roseman, M (eds.). *Preprints of the 6th International Conference of the Association for Computer-Aided Architectural Design Research in Asia (CAADRIA2001 19-21 April 2001)*. University of Sydney, Sydney, 307-310.

Chua, CK, and Leong, KF (2000). Rapid prototyping: principles and applications in manufacturing. World Scientific Pub, Singapore.

Evans, M. The application of rapid prototyping technologies for industrial design and ergonomic evaluation, in: Robertson, SA (ed.). Contemporary Ergonomics 1997. *Proceedings of the Annual Conference of the Ergonomics Society* (April 1997). Taylor & Francis: London, 370-375.

Horton, G.I.; Radcliffe, D.F. (1995) Nature of proof-of-concept prototyping, *Journal of Engineering Design*. v6, 1, 3-16.

Jacobs, PF (1995). Stereolithography and other RP&M technologies: from rapid prototyping to rapid tooling. ASME Press, Dearborn MI.

Khong, CW (2000). A review of applied ergonomics techniques as adopted by product designers, in Lim, KY (et.al.). *Proceedings of the joint conference of APCHI/ASEAN Ergonomics 2000* (November 2000). Elsevier, Singapore, 317-322.

Khong, CW (2001). FCM @ MMU: content creation and multimedia design, in Norman, EW, and Roberts, PH (eds.) *Proceedings of IDATER2001* (August 2001). Loughborough University, 64-69.

McMillan, T. (1990) Multimedia and education, *Computer Graphics World*. v13, 10, 68-72.

Mohamad, M (1998). Excerpts from the speeches of Mahathir Mohamad on the Multimedia Super Corridor. Pelanduk, Malaysia.

Olsen, G (1997). Multimedia design. North Light Books, Cincinnati OH.

Pugh, S (1991). Total design: integrated methods for successful product engineering. Addison-Wesley, Wokingham.

GIS-BASED VISUAL PERCEPTION ASSESSMENT OF MOUNTAIN SKYLINE:

A Case Study of Jinzishan Hill and the Building Layout of an Adjacent Site Planning Project

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Abstract. In this paper, we present a GIS based approach to evaluate the visual perception quality of mountain skyline. Through computer generated analytical maps and perspectives, this tool can assist planners to define the visual reservation scopes for mountain skyline within urban area. It also offers concrete data supporting for appropriate strategy in building layout or site planning to preserve valuable natural skyline scenery.

1. Introduction

In the Chinese Culture Circle, natural mountain skyline plays a significant role in landscape aesthetics (Higuchi, 1983). In urban area, mountain skyline also dominates the visual landscape in which artificial and natural elements mingled. This kind of visual landscape character is one of the most important heritages of China urban planning and is sustaining most Chinese cities' genius loci through out the history (Sun, 1994). But due to modern urban development, natural mountain skylines are always destroyed by improper planning and construction, especially in recent two decades in China. Although most of these damages are the obstruction of visual scenery instead of physically, but unfortunately, because there are few available tools to evaluate the inherent visual structure of urban natural landscape or predict the effect of a developing project precisely in Chinese professional field, planners and managers are feeble in preventing these errors effectively. In this paper, through a case study, we present our approach for overcoming these limitations in planning and management.

The proposed GIS tool is a part of analytic technology of a prototype system which we developed to studying the *Visual Sustainability* of urban natural landscape. This system offers scientific and reliable references for planning consulting, as well as introduces simple analysis procedures for the urban planning practical application. In its technical support, the potential of the use of GIS is demonstrated in the conjunction of system functions of viewshed calculation, overlay operation for visual sensibility assessment and 3D simulation (He and Tsou, 2001). This system can also serve as a substitute of preliminary assessment of site perceiving or planning prediction. It is especially valuable for China urban planning since many detriments in large-scale landscapes are in the sequence of lacking proper prediction (He, 2001).

2. Research Methodology

The GIS based solution in this paper is focused on the visibility of mountain skyline study, and integrate these visibility results with further visual quality description parameters. Furthermore, visual distance, vertical and horizontal visual angels of the mountain skyline are also introduced.

2.1 VIEWSHED ANALYSIS OF MOUNTAIN SKYLINE

Using an ArcView GIS program, we firstly calculate the viewshed of each typical point of the mountain skyline. Then we overlay the visible maps to find the ratio and distribution of the superposition of these visible scopes. Those data demonstrate the continuity of the characteristic points, the integrity of the whole skyline, and the identifiability of typical skyline formation.

2.2 SPATIAL LIMITATION OF SKYLINE VISUAL PERCEPTION

To define the visual perception quality into more reality to match the human vision, we consult human visual ergonomics and psychology of visual landscape perception to establish the limits of visual distance and view angles. The high quality visions are located in the potential development districts for further site planning consideration in either planning rules formulation or project building layout.

3. Case Study

The case study, the Jinzishan hill region in Zhongshan city, Guangdong Province of China, which is the site picked by collaborating discussion of

research team and local government, locates on the edge of urban built-up area. The hill is the prominent landscape element of the surrounding environment. The most distinguishable character of the massif is there are two peaks alongside to each other that build a gentle and diverse outline. Therefore, the physical part of two peaks with the saddle between them is considered as the most significant feature of the mountain skyline.

3.1 SKYLINE VISUAL PERCEPTION QUALITY

In this research, we choose two formations of Jinzishan massif skyline to evaluate the sceneries of different directions. On these two skylines, every thirty to forty meters along the chine a point is picked as the characteristic point in viewshed calculating. Additionally, some significant points that mark out the alternation of the terrain feature are also collected. These points are categorized into different visual significance. Visible areas of the points in same importance are overlaid according to the visual sensibility strategy (Figure 1).

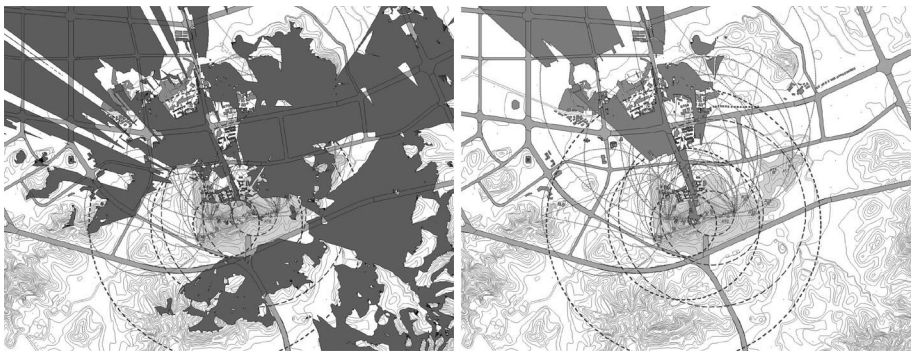


Figure 1. Visible areas of categorized skyline characteristic points: scopes can see both peaks (left); scopes can see the center of the saddle (right).

Besides visibility of the mountain skyline, we also introduce other ergonomics data or spatial scale characters which limit the visual perception quality into this analysis. These information include: visual cone parameters in horizontal visual angels in 60° (upper limit of good vision range), 70° (upper limit of good vision with oculomotor) and 30° (the most comfortable visual perception angle) (Tilley, 1983); critical value of psychology reflection to natural hill vertical view angle in 5° (critical angle to enjoy skyline scenery); 9° (suitable for both skyline and hillside details views) and 20° (cannot observe the skyline directly) (Higuchi, 1983).

These parameters are translated into spatial data and overlaid with the visibility maps. This procedure engenders the internal divisions in variant

visual qualities to the mountain skyline. Accurate computer generated spatial coordinates of these divisions can be employed as site planning reference (Figure 2).

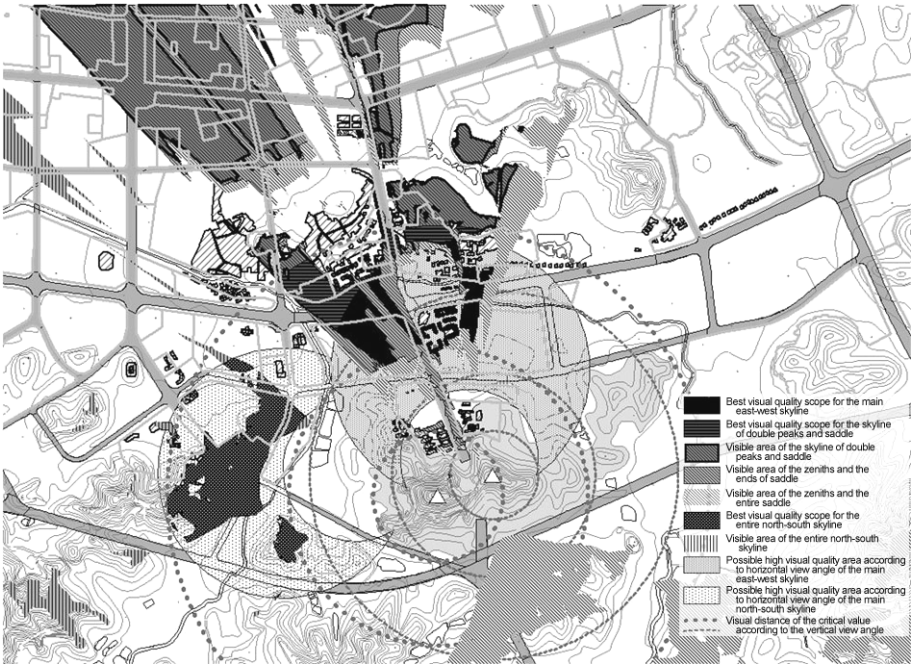


Figure 2. Visual quality mapping of skylines by overlaying viewshed analysis and human visual ergonomics and psychology parameters analysis

3.2 BUILDING LAYOUT ANALYSIS OF ZHONGSHAN CCP SCHOOL CAMPUS

The authors were also invited to evaluate the first stage designing projects of the new campus of Zhongshan Chinese Communist Party School which is positioned in a sensitive landscape place north to the Jinzishan hill. Part of the high visual quality zone to the most important section of the massif skyline situates in the site. And the building height may affect the skyline visual perception along an adjacent urban arterial road northward. There were four design projects represent different building layout models in site planning (Figure 3).



Figure 3. Visual quality divisions introduced from skyline analysis shows the importance of the campus site (left). According to this information, only Project No.4 has no negative effect in blocking the skyline scenery. And Project No.1 also has the potential of avoiding such obstacle (right).

The research team reviewed the viewshed situations of different building layout in these four projects (Figure 4) and compared the building positions

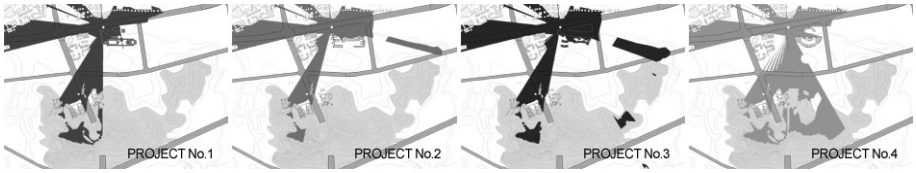


Figure 4. Viewshed analysis of those four projects layout from Baishichong Bridge, which is the best viewpoint to the mountain skyline within the road. Only Project No.4 can see most parts of the valuable mountain skyline.

with the former proposed visual reservation zones (also see Figure 3). We concluded that all of those designs couldn't meet the requirement of regional visual landscape protection mentioned in the bidding document. To create a guidance for further design, based on the general Jinzishan skyline visual perception study, the research team use the above-mentioned GIS tools to create 2D visibility maps as well as 3D site perspectives for multi-possibility site planning evaluation (Figure 5, Figure 6). Finally, a visual

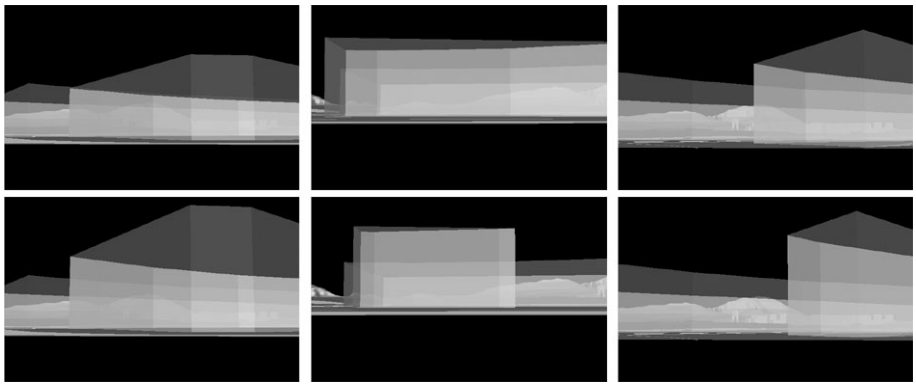


Figure 5. 3D human visual perspective simulation on comparative study of building height and receding line analysis.

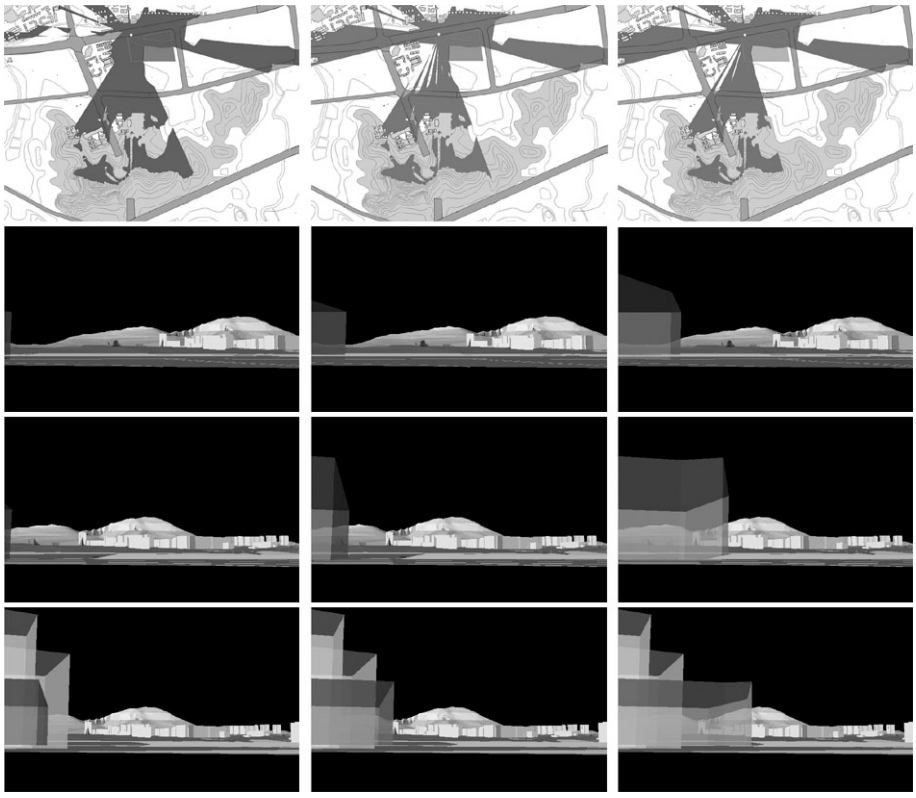


Figure 6.Comparative study of visual corridors. From above to bottom: viewshed maps; view from Baishichong Bridge; view from south sidewalk; view from north sidewalk (with building height comparison). From left to right: the max visual corridor scope plus; the medium visual corridor scope plus; the minimum visual corridor scope.

corridor system is decided to be reserved in the site (Figure 6), and its accurate coordinates are marked (Figure 7). These advices have been adopted as basic regulations to stipulate this development and legalized in the official verdict of instructing further site planning (Zhongshan CCP School New Campus Designing Judging Panel: 2001).

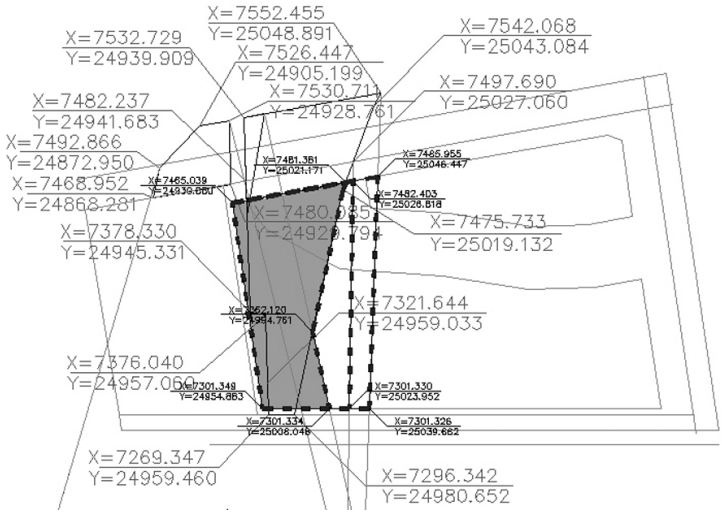


Figure 7. Visual corridor location in precise coordinate values

4. Conclusion

This tool introduced in the case study firstly offers scientific and reliable references for the planning support. Such kind of planning and visual analysis used to be based on manual operation or even surmise in China. The GIS technology promises the accuracy, validity and reliability of this tool. Secondly, this tool has a large potential in professional application. For example, comparing with similar researches, such as the view corridor study of Zacharias (1999), in which use color pencil decorated computer graphics to assess the public preference of urban natural skyline, this tool focuses on the spatial distribution and spatial impact of visual quality. Therefore its analysis results can be more accessible in urban planning and management process. Such functional advantage is also highly recommended by the participating experts and academicians in the judging panel meeting of the case.

There are still some further topics to be discussed. For instance, after calculated the visibility, landscape aesthetics becomes the basic criteria of visual perception quality (Higuchi, 1983; Litton, 1982). An operable

methodology of quantifying the mountain skyline visual formation into aesthetical characters is still in vain. Other problems also occurs in data version and data overlay in system architecture (He, 2001). This tool is still in progress to its ultimate solution in natural skyline assessment.

Acknowledgements

The case study is a collaborative research with the Zhongshan Planning Bureau. The authors wish to acknowledge the energetic support from the cooperative organization, especially the to the following personnel: Vice General, Mrs. LIU Huilin, the Director of Technical Section, Mr. HE Huazhong, and Ms. JIA Wenfeng of the Techincal Section. Mr. ZHANG Zongyu of our department helps us by technical assistance. Other gratitude goes to our colleagues in Zhongshan CCP School New Buildings Designing Judging Panel for their supporting on our suggestions on building layout planning.

References

He, J. and Tsou J. Y.: 2001, GIS-based visual perception analysis of urban natural landscape for urban planning supporting: a case study of Jinzishan hill region, *in* H. Penttila (eds), *Architectural Information Management: Proceedings of the 19th Conference on Education in Computer Aided Architectural Design in Europe (ECAADE 2001)*, Helsinki, August 2001, pp. 505-510.

He, J.: 2001, *CAD Study in Visual Analysis of the Visual Sustainability for China Urban Natural Landscape Planning*, thesis of master degree, The Chinese University of Hong Kong, Hong Kong.

Higuchi, T.: 1983, *The Visual and Spatial Structure of Landscapes*, The MIT Press, Cambridge.

Litton, B.: 1982, Visual assessment of natural landscapes, *in* Sadler, B. and Carlson A. (eds.), *Environmental Aesthetics: Essays in Interpretation*, University of Victoria, Victoria, pp. 97-115.

Sun, X.: 1994. The city should be rich in the pleasures of wild nature – a traditional aesthetic concept of China for urban planning, *Ekistics*, 61, no.364/365, 22-28.

Tilley, A. and Henry Dreyfuss Associates: 1993, *The Measure of Man and Woman: Human Factors in Design*, Whitney Library of Design, New York.

Zacharias, J.: 1999. Preferences for view corridors through the urban environment. Landscape and Urban Planning, 43, 217-225.

Zhongshan CCP School New Campus Designing Judging Panel: 2001, *Cahier of design competition evaluation of Zhongshan CCP School New Campus*, unpublished documents of Zhongshan Planning Bureau, Zhongshan, March 13 2001. (Chinese text)

PERFORMANCE-BASED SIMULATION FOR THE PLANNING AND DESIGN OF HYPER DENSE URBAN HABITATION

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Abstract. The rapid development of the economy and urbanization create great pressure on population of Hong Kong, China and other developing countries. This not only brings great changes on the form and style of the urban sphere, but also, challenges to the natural environment and resources to support urban habitation. Regarding the process of urbanization, the development of the housing industry becomes the focus to resolve the need of materialization for urban living. For this reason, from time to time, technical and economical considerations are always prior to the significance of human settlement environment, humanity, and sustainable development. Considering the deficiency in urban human settlements environment, especially in responsiveness to the natural environment. Information technology (IT) undoubtedly can help to promote and assess the design and planning quality in both environmental and regional microenvironment aspects. A research project-Environmental Responsible Architecture and Urban Design (ERAU)-is established to support urban scale planning, information processing, and computer-aided performance evaluation on both micro and macro building design and planning efficiency.

1. Introduction

The rapid development of the economy and urbanization create great pressure on population of Hong Kong, China and other developing countries. This not only brings great changes on the form and style of the urban sphere, but also, challenges to the natural environment and resources to support urban habitation. Regarding the process of urbanization, the development of the housing industry becomes the focus to resolve the need of materialization for urban living. For this reason, from time to time, technical and economical considerations are

always prior to the significance of human settlement environment, humanity, and sustainable development. The "hardware" approach is often chosen the government agencies as the major means and is given high priority in its implementation process to satisfy the social condition. Based on the measurement of the "hardware", several index tables have been established to guide the development such as average living area per person, construction cost per square footage, and open space per resident. Influenced by the development pattern of western cities, the mode and theory of planning and design follow logical and feature-oriented approach. This helps greatly in many aspects of urban development, for example, the transportation framework establishment, infrastructure planning, urban habitation development, land use control, and density regulation. Yet, at the same time, it also posts new challenges for maintaining a stratified relationship between building complexes and their surrounding environment in terms of functional and spatial configuration.

Quality urban human settlements environment should not only focus on the feature-oriented "hardware" development, but also establish the integration of human and natural environment according to its unique spatial context and urban landscape. The comprehensive design and planning process of unique urban landscape could give residents more direct impact to the sensation than the abstract human settlement environment as well as the in-depth psychological construction mode. For years, the livability and efficiency of the human settlement environment of Hong Kong and China cities have been left ambiguous by the planning, design, construction, property management and real estate sectors. There is no precise and useful control over the performance of the designed and planned urban environment. Especially there is a lack of qualitative tools for design evaluation. Meanwhile, during the early stage of design development, there is insufficient procedure and tools to easily assess the impact to the urban landscape caused by the settle pattern.

Considering the deficiency in urban human settlements environment, especially in responsiveness to the natural environment, information technology (IT) undoubtedly can help to promote and assess the design and planning quality in both environmental and regional microenvironment aspects. Technologically, IT provides a dynamic process for design, management, and supervision of the living environment construction. It enables immediate scientific judgment and response information. A research project - Environmental Responsible Architecture and Urban Design (ERAU) - is established to support urban scale planning, information processing, and computer-aided performance evaluation on both micro and macro building design and planning efficiency. The work is to develop the predictability and descriptiveness of performance evaluation tools, to investigate the methodology to integrate these tools into early design stage, and to reduce the faults in planning and design due to the ignorance of building performance.

Five major research components which have complex inter-relationships are included in ERAU: a. urban visual sustainability; b. urban wind environment

and natural ventilation; c. thermal comfort and building energy efficiency; d. natural lighting for urban space and architecture; and e. acoustic quality for urban planning and building design. In this paper, research works from above research components are selected to demonstrate the mechanism and discuss the outcomes. Research works related to urban visual sustainability is discussed in another CAADRIA 2002 paper, GIS-based visual perception assessment of mountain skyline: Case Study of Jinzishan Hill and the Building Layout of an Adjacent Site Planning Project by Mr. Jie HE & Prof. Jin-yeu TSOU

2. Urban Wind Environment and Natural Ventilation

Wind environment in building complex and indoor ventilation is the key elements of physical comfort. Moreover, the efficiency of ventilation is directly related to the energy conservation of building. Therefore, this has become one of the major direction of "Green architecture" in the sustainable development. Maintaining smooth ventilation and avoiding returned exhausted fume into the indoor environment, maintaining fresh air of suitable air speed in outdoor environment, and reduce pollution, are the basic consideration in the planning and design of architectural wind environment. For a big country like China, different regions have completely different considerations of wind environment. The different local geographic conditions, insulation and cooling requirements become great challenge to the architectural wind environment design in China.

For many years, the research team has focused on the application of Computational Fluid Dynamics (CFD) in architectural design of different scale. We mainly use computational fluid dynamic on wind load on the building elevation, wind environment at the building complex and the indoor ventilation for computer simulation. Combing with the visualization technology, information of wind pressure and air flow pattern can be provided to the designers at the early stage of design. In this case, designers can improve the physical environment before too much commitment has been made for a design scheme. Compared with the traditional method of wind tunnel testing and field measurement, computational fluid dynamic does not only save time and cost, but also has many advantages in technology (Tsou, 2001).

2.1. AIR MOVEMENT AND REGIONAL URBAN WIND EFFECT OF "SKY GARDEN"

Collaborating with HKSAR Buildings Department, research team applies CFD technology to investigate the urban wind phenomenon associated with the "green features" suggested by the government environmental design guideline. These features include wind catcher, sky garden, podium garden, and wing walls etc. Different design configurations have been identified as the key factor to investigate, and understand the effectiveness of the sky garden, and, establishing

the basic rationale to assess the performance are the main objectives. In our case study, several high-rise residential blocks located at the HK Island have been chosen as the basic configuration to carry out the test. CFD models have been built for investigating the configurations such as minimum height, the effectiveness to balance the regional wind condition, safety considerations under extreme wind speed, the location of the garden, and contribution on thermal comfort. Air speed chart and the air movement diagram are generated to allow building controllers and architects to draw major hypothesis for giving rationale on the sky garden design. (Figure 1).

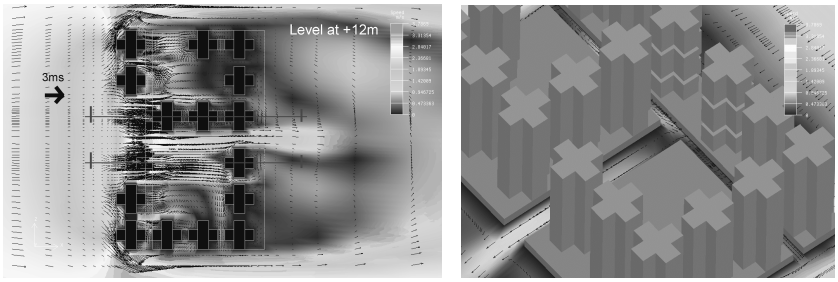


Figure 1. Left: Wind environment at building complex; Right: The effect of building form on wind environment at pedestrian level

2.2. NATURAL VENTILATION STUDY FOR HIGH-RISE RESIDENTIAL BLOCKS

Cooperating with the Kenzo Tange & Associates, we evaluated the physical environmental condition of the project, and made suggestions regarding natural ventilation, daylighting, and noise impact. We also made use of this integrated analysis to design an environmental friendly underground car park. The wind environment of this project covered different scale of building design issues such as extreme air movement caused by the building cluster and geometry, the space between the building blocks, opening location for natural ventilation, wing wall design associated with the openings, and the location of major inlets/outlets. Based on different kinds of climatic conditions, CFD models are built to simulate the wind environment and indoor air movement. The air flow patterns surrounding the building complex and at the activity zones are analyzed to identify potential problems. For example, the wind noise caused by the "near gap" between buildings and the re-entry problem of the kitchen exhaust are two major areas for improving the design after reviewing the simulation outcomes (Figure 2). In the environmentally friendly underground car park design, we also applied the CFD as design exploration tools to investigate the integration of “wind scoope”, “wind catcher”, and "chimney effect" into an underground carpark in order to maintain the required air exchange rate using natural ventilation (Figure 3).

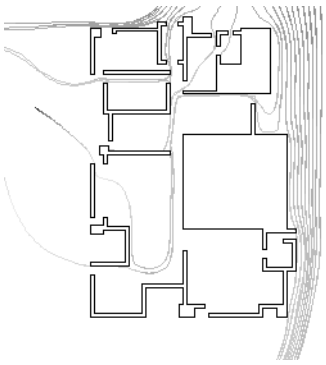


Figure 2. Ventilation of Block A in Winter.

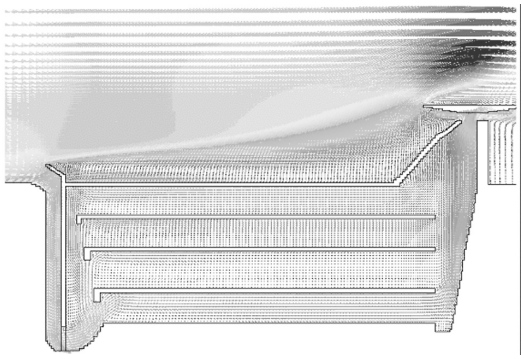


Figure 3. CFD simulation of the car park.

3. Daylighting for Buildings and Open Space Environment

Through daylighting simulation, the impact of daylight on the physical environment can be studied. This includes impact of direct sunlight, diffused light and reflection from other objects in the environment. Daylighting simulation results provide supplement information to designers to consider design issues such as daylight factor, illuminance, solar radiation, and visual comfort. Since providing proper shading and reducing radiation gain are two main concerns related to the energy conservation strategy for sub-tropical climate, the simulation outcomes with graphical representation enhance the efficiency of the "what-if" analysis process in planning and design of building complex. Because the luminance and glare could affect human comfort at both physical and psychological level, the research team also works with architects to investigate design strategies to improve this important quality factor. Other daylight performance issues been investigated by the research group include the location and adjacency of building groups, site layout, inter-block shading strategies, and solar access.

3.1. DAYLIGHTING ANALYSIS FOR HIGH-RISE RESIDENTIAL BLOCKS

In the daylighting analysis of this project, we simulated the inter-block shading environment in different seasons. Besides, we simulated the condition of radiation gain on building elevations in different seasons for energy saving design and the consideration of building enclosure (Figure 4). Moreover, we evaluated the daylighting environment of different activity zones for efficient planning and design of the outdoor activities and facilities, which in return, increase the design quality and comfortability for high density urban settlement.

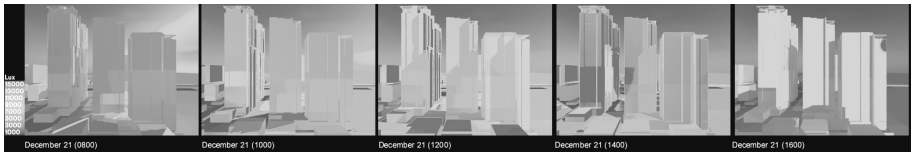


Figure 4. Heat radiation receiving in building façade: The direct sunlight to Block B is shaded by adjacent building blocks in winter on the west.

4. Urban Noise Simulation for Room Acoustics

In these projects, we now are focusing on the simulation and the analysis of the acoustic environment at two levels: urban noise and room acoustic. For the sub-tropical hyper-dense urban settlement, besides "Heat Island" phenomenon, "Sound Island" also becomes a major concern of the planning of our future urban environment. Urban noise includes traffic noise, construction noise and neighboring activities. Noise could cause serious disturbances to comfortable living, especially in the dense living environment with very limited living area available to individuals. Psychologically, urban noise and room noise could seriously affect people's perception regarding the crowdness and adaptation of the space usage. Considering Hong Kong's unique habitation pattern, there is an urgent need to apply good practice in urban planning and building design to ensure the acoustic quality for liveability purpose. Yet, improper planning due to the rapid urban development has increased the acoustic disturbance to the residential environment.

With acoustic simulation and scientifically visualization, designers can have a thorough understanding of the acoustic environment, and hence assisting effective building design and planning strategies to improve the acoustic quality of the living environment. In the acoustic simulation, we use Raynoise, which, is based on geometrical acoustics that 'sound waves' are considered as 'sound rays'. The algorithms Mirror Image Source Method (MISM) and Ray Tracing Method (RTM) are employed which are effective in providing precise noise source information for architectural acoustics (Kang, Tsou and Lam, 2000).

4.1. NOISE STUDY FOR HIGH-RISE RESIDENTIAL BLOCKS

Since the building site is adjacent to major traffic route of the city, the road noise has great impact on the residential blocks (Figure 5). We examined the effectiveness of different architectural approaches to reduce the noise impact, and the protection of the central courtyard from the unpleasant road noise (Figure 6). The location and effectiveness of different types of noise barrier were tested, and master site plan was revised according to the information given by the simulation. Sound pressure level (SPL) and reverberation time of the urban noise are two main components which cause discomfort, and the research team focused on the simulation of SPL in the urban context. Owing to the building configuration and materials adopted by Hong Kong high-density

settlement, special attention has been given to the treatment of low frequency noise. The low frequency noise as other research shown will have much greater impact on elderly and children as they spend most of their time in their flats. The hearing system of children is sensitive to the damage caused by the exposure to low frequency noise, and elderly will have difficulty to recognize the speech when the background low frequency noise level is high. We also consider the sound pressure level distribution of the open space in different frequencies to provide a base for architects to plan for layout and different facilities.

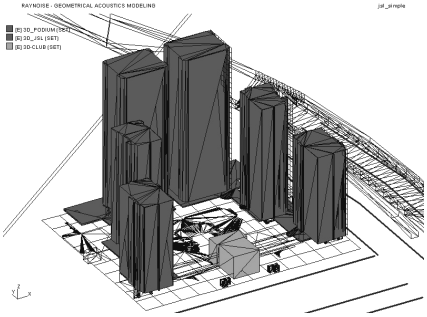


Figure 5. Noise simulation model.

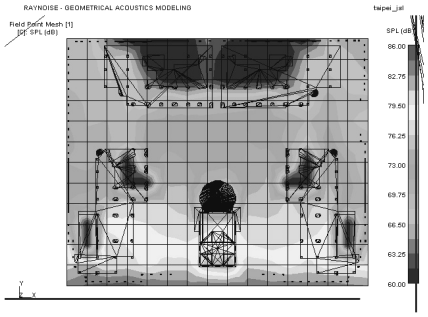


Figure 6. Impact of noise on the open space.

5. Conclusions

With the increasing living quality, comfortability and responsiveness to the natural environment will become the major evaluation criteria for assessing the development of high-density urban habitation. The studies and applications investigated are not only for individual projects or specific technology development, but also for providing an integrated mode that supports environmental planning and design for sustainable development at humanity level. We hope that through information collection, information generation, information analysis and information visualization, we can support intelligent design, and increase the efficiency and liability of urban planning and the architectural design.

Meanwhile, there are many issues that need users' attention or further research according to the experience received from the project implementation process:

a. Extensive background knowledge is required to set up the correct parameters to generate meaningful simulation outcomes. For example, it is not an easy task to detect the mistake embedded in a CFD simulation and determine the cause of the error.
b. For maximizing the effectiveness of the use of simulation tools described in the paper, multidisciplinary collaboration is needed to interpret the outcomes and to develop alternative approaches.
c. In order to benefit from the scientific simulation process, planners, designers, or engineers should not merely treat it as a kind of post-design

evaluation activity, but consider the process as another mean of design innovation generation.

d. Since there is no "true" exchangeable design model data format, valuable time could be easily wasted by tedious works related to the model preparation and data conversion. Defining proper level of details for simulation and establishing design information management structure are two important considerations before carrying out simulation processes.
e. Overlaying different kinds of building deisng/performance information provides designers and planners further opportunities to evaluate their design decisions, therefore further research has been initiated to integrate the VR system and rapid prototyping system to simultaneously represent geometric design information and non-geometric building performance information.

References

Chow, Benny: 1997, Computation in daylight architecture. Proceedings of the Second Conference on Computer-Aided Architectural Design Research in Asia (CAADRIA97). National Chiao Tung University, Taiwan.

He, Jie: 2001, CAD Study in visual analysis of the visual sustainability for China urban natural landscape planning, Thesis of master degree, The Chinese University of Hong Kong.

He, Jie and Tsou, Jin-Yeu: 2001, GIS-based visual perception analysis of urban natural landscape for urban planning support: a case study of Jinzishan hill region. Proceedings of Education for Computer Aided Architectural Design in Europe (ECAADE 2001), Helsinki, Finland.

Kang, J., Tsou, J.Y., Lam, S.: 2000, Integrating scientific visualization into architectural curriculum for teaching acoustics and noise control. Proceedings of International Conference on Architectural Education Exchange 2000 - Teachers in architecture: facing the future, University of Sheffield, UK.

Kang, J., Tsou, J.Y. and Lam, S.: 2001, Sound Propagation in Urban Streets: Comparison Between UK and Hong Kong. Proceedings of the 8th International Congress on Sound and Vibration (ICSV 2001). Hong Kong

Lim, Bernard, Leung, Man Kit and Benny CHOW: 1999, Passive environmental strategy guidelines and design parameters for energy efficient architecture: application to public housing for single senior citizens - a new prototype in Hong Kong SAR. Proceedings of the 37th Annual Conference of the Australian and New Zealand Solar Energy Society - Solar 99 Opportunities in a Competitive Marketplace. Deakin University, Australia..

Tsou, Jin-Yeu: 2001, Strategy on applying computational fluid dynamic for building performance evaluation, Automation in Construction 10 (3), 2001. pp. 327-335.

Tsou, Jin-Yeu and Zhu, Yimin: 1998, Study on the performance of airduct. Proceedings of International Symposium on Computational Technologies for Fluid/thermal/chemical Systems with Industrial Application, San Diego.

COLLABORATION SUPPORT SYSTEM FOR CITY PLANS OR COMMUNITY DESIGNS BASED ON VR/CG TECHNOLOGY

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Abstract. This paper reports the collaboration support system for city plans or community designs based on virtual reality (VR) or computer graphics (CG) technology. This time we report to elaborate the extended potable VR equipment and expression method with CG to allow for the realistic viewing of night scenes, and apply to real projects.

1. Introduction

A process of a city plan or a community design that includes both daytime design and nighttime design is a kind of a social activity. It is very important to collaborate with many participants who are not only professional people such as planners, designers, engineers and administrators but also non-professional people such as clients and citizens. We have developed a "VR/CG-based Collaboration Support System". This system is capable of providing a dynamic virtual experience to a city plan or a community design allowing many people to examine it at a time through VR scenery. It can also be effectively used as a design or communication medium and substantially improve design/review efficiency. Once a 3D virtual space is constructed based on design drawings, participants can select portable VR equipment reported in CAADRIA'98 or dome-screened VR equipment reported in CAADRIA2000 according to their purpose to experience and evaluate the design. We also elaborated expression method with VR to allow for the realistic viewing of night scenes reported in CAADRIA2001.

And we have also applied and evaluated our latest system to real projects. This system also allows people to have a spatial feeling by virtual walking around, compare multiple plans, and make design changes interactively and easily. In this paper, we report to elaborate the extended potable VR equipment and expression method with CG to allow for the realistic viewing of night scenes, and apply the latest system to real projects.

2. System Improvement

We elaborate the extended potable VR equipment and expression method with CG to allow for the realistic viewing of night scenes.

2.1. EXTEMDED PORTABLE VR SYSTEM

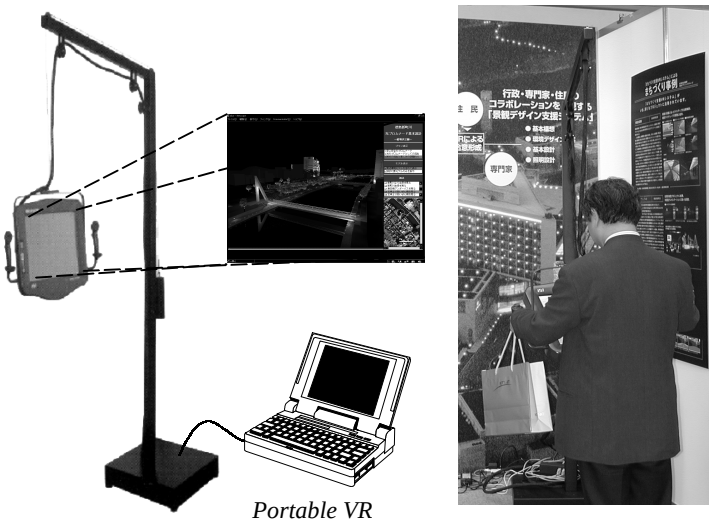
The portable VR system is based on PC (Windows 95/98/NT/Me/2000). Its software circumstance consists of a VRML (Virtual Reality Modeling Language) browser (Cosmo Player 2.1x) and a JAVA applet on a Web browser (Netscape Navigator 4.06~4.78 or Internet Explorer 4.x~5.5). The following explains the main functions for the portable VR system:

1) Project participants walk-through and bird's-eye view in a 3D virtual space. Their position and orientation in a 3D virtual space represent on a 2D map in real time. If they set position and orientation by dragging mouse on a 2D map, the viewpoint of a 3D virtual space is represented in real time. A field of view is also changed. When they set wide-angle, they review all the world. When they set narrow-angle, they review near sense of their depth perception.
2) They compare multiple plans, daytime design and nighttime design interactively and concretely.
3) They review to translate and rotate a design element, and create a new plan loading a new design element such as a tree or a illuminator from 3D database.
4) They change a texture or a color of a design element such as pavement or building façade interactively.
5) They measure a scale of a element in a 3D virtual space.

This time we develop the device driver software to connect the potable VR equipment with a VR in/out device. One of a VR in/out device is named "Window-VR system". This consists of a 17" display with touch screen, handgrip buttons emulate joystick buttons, 3 degree of freedom orientation tracking. The display is hung in the air. Project participants grasp the handgrip buttons of both sides of the display and use touch screen, operate a 3D virtual space more friendly and sensuously than with mouse. With this

device driver software, a driving simulator system also be applied. The following explains the specification of the software:

1) A design participant rotate or tilt the display with handgrip buttons or operate joystick where they want to review.
2) Numerical values of its position or orientation are acquired from 3 degree of freedom orientation tracking if the display is rotated or tilted or from the joystick if the joystick is operated.
3) Acquired values are translated a VRML spatial frame of reference. Then the new viewpoint data is calculated.
4) The new viewpoint data is represented on a 3D virtual space via VRML EAI (External Authoring Interface).



Window VR *Portable VR* *a scene of operating Window VR*

Figure 1. Connecting the potable VR equipment with the VR in/out device (ex. WindowVR)

2.2. EXPRESSION METHOD WITH CG TO ALLOW FOR THE REALISTIC VIEWING OF NIGHT SCENES

An actual distant night scene produces an impression of bustle with a mass of illuminators. On the other hand, when a night scene is represented by CG, an emission part of an illuminator by painting over with emissive color is usually represented. With this method a distant night scene of CG is represented as dark as pitch because of resolution. To get rid of the difference between actuality and CG, to represent a distant night scene is usually re-touched. But there are a lot of trouble to re-touch and it is difficult to repeat trial and error. To solve this problem and simulate more photo-realistic night scene image, three functions are developed on the

lighting simulation software named “Inspire”. The following explains the functions:

1) “BLOOM” determines that bloom glare (bright spot around a bright pixel - such as that in which a light source is located) is simulated.
2) “CORONA” determines that corona glare (bright spot with rays emanating from a bright pixel) is simulated.
3) “EXPOSURE” effect control for photo-like rendering. Zero means ordinary rendering which assumes infinitesimal time. Values other than zero make sense only if exposure textures are present in the scene. In photo, especially night ones, the exposure time must be quite long which results effectively in superimposing reflection from undulation waves on water surface that, in turn, is available with exposure texture. The value of exposure time for rendering should be agreed with time interval (end time) defined for exposure texture.

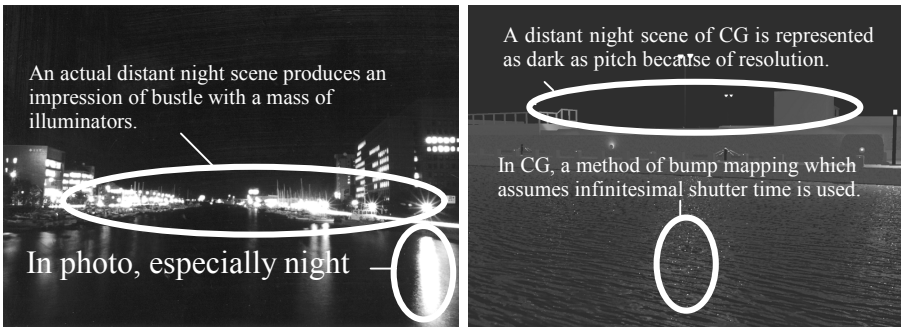


Figure 2. Comparison of a photo(Left) and existing CG(Right).



Figure 3. New expression method of CG (Left: eye effect; Right: camera effect)

4. Application of the System to the Real Projects

To evaluate our latest system, we apply this to multiple real projects.

4.1. STREET OF STORES RENEWAL ENTERPRISE

This project is a street of stores renewal enterprise of the U city government. This street is located one of the center of commerce in U city. But in recent years commerce of this area become hollow. As you know this problem is not only this area, but also many areas in Japan. From 1960's until now, residential areas are developed in the suburbs of a center of cities. Public and private facilities also move to the suburbs. Less people live in the center of the city. And a center area of cities don't correspond to the progress of motorization. Stores of a center of cities tend to be defeated by suburban supermarkets.

For revitalization of this street we continuously support this enterprise with our VR system for about two years from April 2000. Participants is composed of the U city government, planners, the chamber of commerce, the association of town center management and inhabitants. The VR system is used not only on study meetings among professionals per a week but also on study meetings among both professionals and citizens per a month. This is useful for simulating the plans and sharing the concrete design images with participants. There are four steps in the process:

Step1) We make the 3D virtual space of the actual world based on ground plans and photos of building facades.

Step2) We simulate putting up electric wires in the ground and removing existing electric light or telegraph poles and arcades of the street in the 3D virtual space.

Step3) We make the 3D virtual space of four road alignments: 1) straight alignment, 2) curve alignment (two patterns) and 3) branch alignment. Project participants compare plans and agree on the direction of curve alignment. They review from driver's and pedestrian's continuous viewpoint. Then multiple kinds of curve alignments are reviewed.

Step4) We make the 3D virtual space of a landscape design. Participants compare multiple design alternatives of gardening spaces, symbol trees, benches, illuminators, bollards and pavements interactively.

In the near future, building facades is designed with VR system.

4.2. BALLPARK RENEWAL PROJECT (NIGHT SCENE DESIGN)

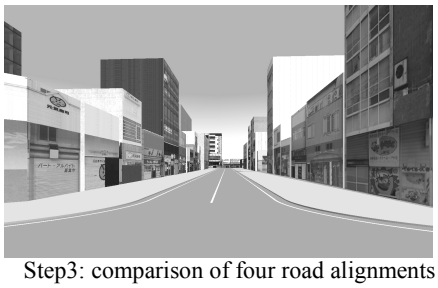
This project is the H ballpark renewal project. The architect creates the concept of the ballpark like MLB (Major League Baseball) ballparks. One of its characteristics is that its form is not linear symmetry. The site of this



Step1: the actual world



Step2: simulation of putting up electric wires in the ground and removing poles and arcades





Step3: comparison of four road alignments



Step4: comparison of landscape design

Figure 4. Street of stores renewal enterprise.

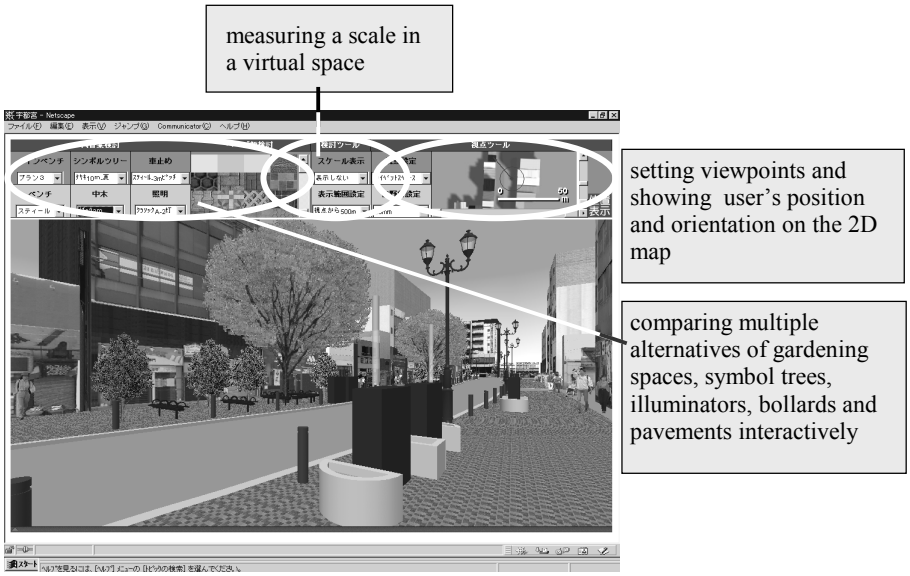


Figure5. Interface of portable VR system (Step4)



Figure6. H ballpark renewal project (Left: 65 days on games; Right: rest 300 days)

project is along the Shinkansen line. The architect designs the low stands behind the left fielder that passengers of the Shinkansen can watch and enjoy the baseball game. Baseball games are usually held at night for about 65 days a year. And also for the rest about 300 days when there are no games, this stadium is placed as landmark of this city. The architect collaborates with the lighting designer to design both 65 days design and 300 days design of its night scene. The lighting designer design but at the first stage he doesn't have a enough presentation tool, only the re-touched CG. Project participants can't share his design image. We support and simulate high minutely with "BLOOM" and "CORONA" functions and at last they can share the concrete image.

5. Results and Conclusion

With this system, participants' design and review city plans or community designs in the real projects. These features are not provided by conventional model, perspective or CG. Also, it is needless to say that these projects are good examples of collaboration. In the future, we make effort to create more realistic VR image.

Acknowledgements

We would like to thank to many participants of projects.

References

Abrosimov, D. et al: 1999, Computer Simulation of Water Surface View, Proc. of 9th International Conference on Computer Graphics & Vision GRAPHICON'99, p.255-260.

Fukuda T. et al: 2001, Collaboration Support System for Nightscape Design based on VR Technology, *CAADRIA2001*, Sydney, pp.103-111.

Fukuda T. et al: 2000, Collaboration Support System for Nightscape Design based on VR Technology, *CAADRIA2000,* Singapore, pp. 501–510.

Fukuda T. et al: 1998, Collaboration Support System for Public Design, *CAADRIA'98,* Osaka, pp. 299–307.

Integra, Inc.: 2001, White Papers: Inspirer, *http://www.integra.co.jp/eng/products/inspirer/index.htm*

Sasada T.: 1999, Computer Graphics and Design, Proceedings of The Fourth Conference on Computer Aided Architectural Design Research in Asia, pp.21-29.

Spencer, G.et al: 1995, Physically-Based Glare Effects for Digital Images, SIGGRAPH'95. Conference Proc., p. 325-334.

Web3D Consortium: 1999, External Authoring Interface Working Group, http://www.web3d.org/WorkingGroups/vrml-eai/

Virtual Research Systems, Inc.: 2000, WindowVR, http://www.virtualresearch.com/

ENVIRONMENTAL DESIGN WITH HUGE LANDSCAPE IN REAL-TIME SIMULATION SYTEM

Real-Time Simulation System Apply to Real Project

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Abstract. This paper is the culmination of a period of studying and participating in certain real project on environmental design with real-time simulation system application. The focus of this paper is on understanding that a generally real-time simulation system, can render a complex scene that consisted by a huge landscape model with millions polygons and building models with thousands details. It is also more than just a collection of unorganized techniques. This paper must dual with issues of scene elements management as a front end that efficiently provide the ability to process complex and moving objects in a physically realistic way. We establish a platform providing good support for the environmental designers.

1. Introduction

Currently, real-time simulation systems are frequently used in interior and industry designs. Comparing with environmental design, the scales of interior design and industry design are very small. An indoor space and an industry product have a constricted data, which can be processed by PC easily. The three-dimension can be completely represented by real-time simulation system.

In contrast, real-time simulation systems are rarely applied to environmental design. The reasons were shown by following:

-Super computer is expensive, environmental designers and design teams are not available to afford the cost of it.

-PCs are not able to render a smooth moving scene with a large landscape model in real-time, because PC is unavailable to process the millions polygons less than 1/30 second.
-Real environmental space is extremely large with uncountable elements. It is difficult for modelers to build an environmental model with full details.

After the Graphic Processing Unit (GPU) was invented, the mentioned situation has improved a lot. GPU replaced the CPU to render the millions of polygons on scene inside PC. According to *n*VIDIA®, their high-end GPU could render 31.5 millions polygons per second. Therefore, this research started to use a PC-base real-time simulation system as an environmental design tool. Before this paper, we have been applying that system to certain small projects. After that, we found that the GPU is not the only way to increase the rendering speed. The scene elements management techniques could also improve the rendering speed and the detail of models; PC can represent a complete scene with many details. Therefore, this research organized these techniques and applied it to a real project that consisted of a huge landscape. This research will show the concepts of the techniques and how did them work. After that, it will present that how they improved the scene in the project.

2. The Project

2.1. BACKGROUND OF THE PROJECT

The study employs a real project of a forest park which is currently under construction based on a municipal development plan in Taiwan. A real-time simulation system was actually applied to this project. This forest park was already existed in the city many years ago. Some of the facilities in this park had already been damaged and some of them had been useless for the citizens. The city government had decided to renew some facilities and build up some new settings for better use of the park.

The total area of the site was 2.3 kilometers x 2 kilometers. This research prepared a terrain model with 320k polygons, roads data, trees data, aerial photographs, trees mapping data and humans mapping data.

2.2. CONCEPT OF REAL-TIME SIMULATION SYSTEM APPLICATION

At the beginning of this project, our team members had no idea to make a real-time simulation system. After discussion, we tried to use the system as a design tool. The reason was shown by following:

-This research team was a Japanese team but the site was far away from the team in Taiwan. Team members could not reach the site often. Real-time simulation system could be a tool to check the site in anytime and any place.

-The designers had certain alterative ideas. We wanted to compare all of them in real-time.

-The system could transform objects in real-time. Therefore we can check the scale by dragging the objects inside the scenes. After the decision was made, we save them to a file.

-This system was a creative system. Team members wanted to find the possibility of this system for the research

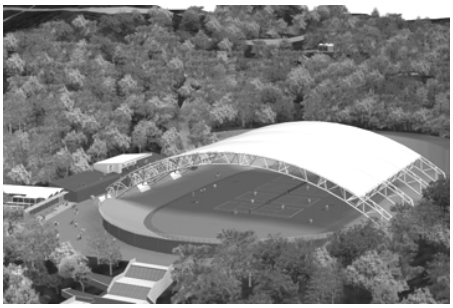


Figure 1. Forest park

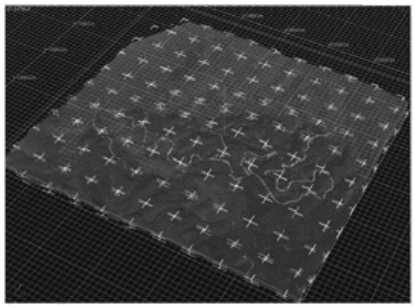


Figure 2. Split the landscape

3. The Techniques

In most environmental design cases, the total amount of polygon data is too large. Even the scene is rendered by PC with highest performance, but a smooth moving scene is still not possible to be represented on display. At the beginning of that project, we tried to render the scene without any scene elements management process. The frame rate of rendering was less than 3 frames per second, but the acceptable frame rate for human eye is 18-30 frames per second. Therefore, we invented or introduced some management techniques to adjust the frame rate to a relatively smooth level by the various scene elements management techniques.

3.1. SPLIT MODEL

For a higher speed rendering, object size is an important consideration. There has a rule inside the real-time simulation system. Before rendering a scene, the system has to check the entire objects inside the scene. If an object is inside the view frustum then the system will keep it, otherwise

object is inside the view frustum then the system will keep it, otherwise leave it aside. After that, the system transforms the objects in polygons, which the system has kept, in order to render them. We split the 320k polygons landscape into 100 smaller sub-landscapes, each of them with 3.2k polygons, as shown *Figure 2*. After the model was split, the frame rate of the scene is greatly improved, because only the sub-landscapes which appear in the view frustum will be taken into account, as demonstrated in the right panel of *Figure 3*. The left panel of *Figure 3* shows the landscape model appearing in the view frustum, all polygons were transformed without splitting. In this case, the scene was displayed slowly.

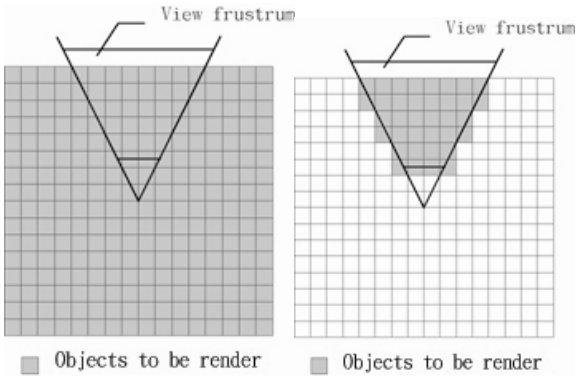


Figure3. Left panel: Single landscape model. Right panel: Split the object in to small prices.

3.2. LEVEL OF DETAIL (LOD)

The essential idea was to draw a high-resolution representation, if an object occupies a large display area on the screen. During the object moving away from the viewer's point of view and being smaller then draw a lower resolution representation. An acronym used for this term is LOD.

3.2.1. Discrete Level of Detail

There are two types of LOD. The term discrete level of detail (DLOD) is used when there are small numbers of representations for the object and the selection of representation is based on some simple criteria such as distance from eye point or the percentage of the display area. This technique is suitable for model with sharp shape, such as building. In this case, we prepared all models in high, middle and low resolution versions for the forest park, as shown in *Figure 4*.

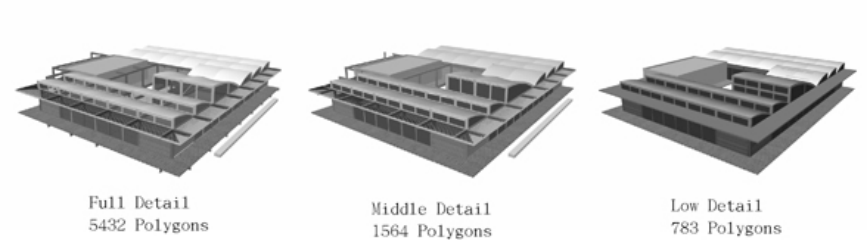


Figure4. The 3 levels of LOD

3.2.2. Continuous Level of Detail

The term continuous level of detail (CLOD) is used when the numbers of representations are potentially large and the object itself can be a complex process. This technique was introduced by Virtools®, which suitable for organic form such as landscape. Therefore, this technique was applied to the terrain model. As shown in *Figure 5,* when the terrain model is larger than 50% of the screen size, it is rendered at full polygon resolution. When the terrain model is smaller than 10% of the screen size, it is rendered with a minimal polygon resolution. Between those two screen sizes, the polygons are decreased by the contraction edge method automatically. As shown in *Figure 7*, the left hand side is the original model. The right hand side is the result that reduces 50% from the original model.

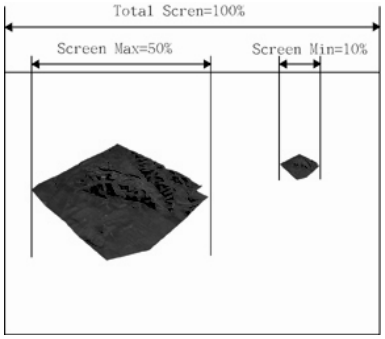


Figure5. Polygon resolution is controlled by screen size

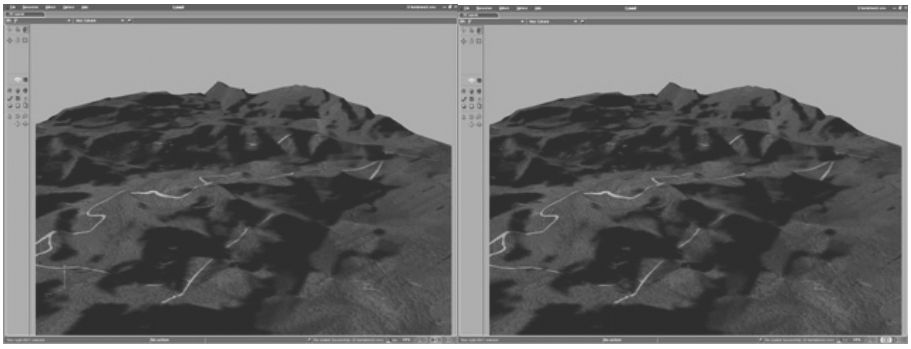


Figure 7. The qualities of both images are similar but rendering speeds are quite different. The Left panel is rendering without CLOD. The right panel is rendering with CLOD.

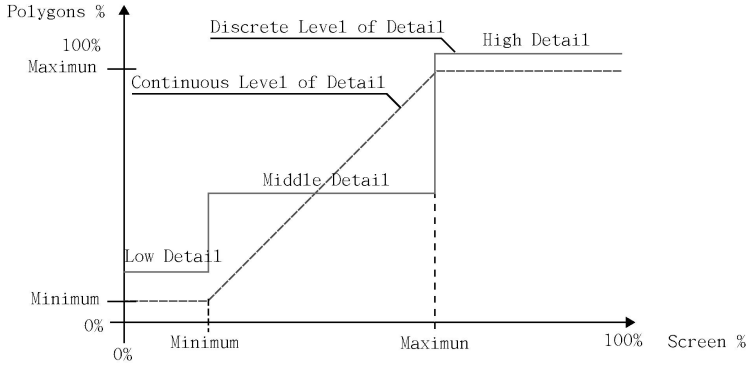


Figure8. Comparison between continues and discrete level of detail

3.3. REMOVE INVISIBLE OBJECT

Model visibility is determined by the position of the model. When the model was covered by the other model in front of it, it will be removed automatically. This situation happened with a complex landscape or indoor environment. As seen *Figure 9*, we used radiate beam as the tester. When Object is under the radiation from view point, that object will be taken into account. Otherwise, it would be aside. This step is a pre-process step before transforming the objects to triangles. Through the mechanical determination, real-time simulation system just renders the minimum polygons on scene. This is the most economic way to make the scene display faster.

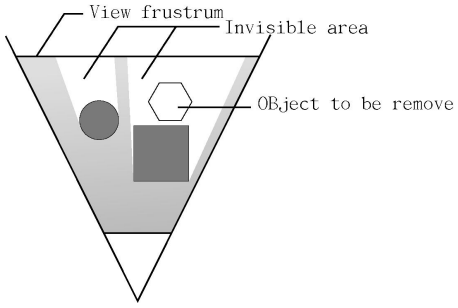


Figure9. Remove the object from the invisible area.

4. The System

4.1. SYSTEM INTRODUCTION

This system was designed for checking the environmental design we made. It included the features as traditional walk through simulation and specially aimed to design, which were shown as following:

-Collision detection can keep away the back side of the models. Viewer must keep away the place they cannot go as real world.

-Gravity fixes viewers in the same eye level. We tried to use gravity to constrain the perspective of viewers

-Viewers can add new elements in real-time. They can choose the element and drag it on the scene.

-The system allows that viewers change the objects scale and position by dragging them.

-Viewers can change the alterative design in real-time. Viewer just chooses the alterative design, and the system will display it immediately.

4.2. PROCCESS FLOW

The process of making real-time simulation system can be divided into five steps. Step 1, we gather all the data from the site, for example, 3D models, GIS and Photos. Step 2, the data was converted to 3D models by modeling software or 3D scanner. Step 3, modeler grouped all models together to a scene within lighting setting, material setting and alterable models. Step 4, Modeler assigned attribute and behavior to the objects. Programmer produced an interface aims to the users' requests. Step 5, export to real-time simulation system for test and debug.

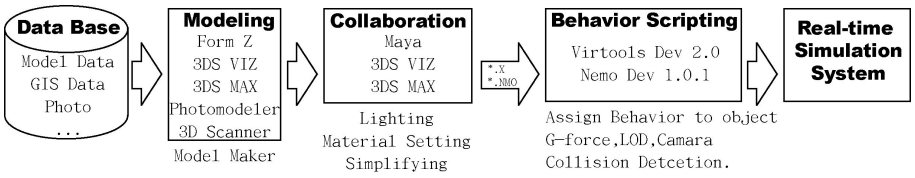


Figure10.This is process flow of making real-time simulation system.

5. Conclusion

Real-time simulation was applied by environmental design successfully in this research. We increase the frame rate up to 20 frames per second. Because of the techniques help us to manage the large model within millions polygons. High performance computer also help us to display more elements on scenes. Environmental designer can design in 3D landscape in real-time. Designer can check their design in real-time also. We are convinced that real-time simulation will be a popular tool for environmental design in near future.

References

Kaga A.:1999, Collaborative Design System for Citizen Participation in Planning Public Road Projects, CAADRIA, Shanghai, pp.225-234.

Kaga A.: 2000, Collaborative Design System for Citizen Participation, CAADRIA, Singapore, pp.35-44.

Sasada T.:1999, Computer Graphics and Design, CAADRIA99, Shanghai, PP21-29.

Sasada T.:1995, Computer Graphics as a Communication Medium in the Design Process, CAAD Futures'95 International Conference,Singapore,pp.3-5.



5

VIRTUAL ENVIRONMENT & KNOWLEDGE MANAGEMENT

5

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THE ROLE OF ADVANCED VR INTERFACES IN KNOWLEDGE MANAGEMENT AND THEIR RELEVANCE TO CAD

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Abstract. This paper introduces knowledge management and computer aided visualisation as a key in establishing both valuation and value creation capabilities in the enterprise where dissemination of knowledge and effective sharing of information through collaboration spur creativity and stimulate business practices. The paper draws an original approach for the design and development of a universal information/knowledge visualisation tool and outlines the mechanics that enable the working prototype that focuses on CAD.

1. Introduction

Rapid progress in computer networks and a growing access to computers enable the emergence of new forms of highly dynamic organisations where dissemination of knowledge and effective sharing of information through collaboration spur creativity and stimulate business practices. More traditional horizontal enterprise infrastructures are strongly constrained and not well suited to support collaboration and the dissemination of knowledge unlike recent vertical business models.

2. Knowledge Management

In the new economy knowledge**,** assets and intellectual properties are expected to increasingly play a dominant role in establishing both valuation and value creation capabilities in such enterprises. Companies such as British Aerospace, Microsoft, Oracle and Autonomy are testament to that. Czerniawska and Potter (2001) examined the law of diminishing returns that observes that when new inputs are added to a process, outputs will not be increased by a similar amount. However in particular situations the law of increasing returns is present where the more goods are produced, the lower the costs or time to market. This discovery is credited to Theodore P. Wright, an engineer, who in 1922 calculated that the labour required in assembling a plane declined by 20 per cent with each doubling of production experience. The introduction of the learning curve and its widespread acceptance in business in the 1960s when applied by the Boston Consulting Group on a number of varied businesses showed the same pattern, costs fell as experience rose. Czerniawska and Potter further argue that understanding why this concept works is through the exploitation of information, i.e. the knowledge of the production process.

2.1 CASE STUDIES

In May 1997 British Aerospace (BAE) created the Virtual University (Heisig and Vorbeck, 2001) when it was decided that the company's growth depended on knowledge and know-how. When considering a high technology company such as BAE is easy to see that the company's knowledge and innovation is embedded within their products and customer services. Intelligent research and retrieval techniques based on Autonomy technologies (www.autonomy.com) were developed to provide users with relevant and timely information especially when considering the company's geographical spread. It is worth noting that different organisations and businesses have different needs when considering knowledge management solutions. Also of interest is IBM's effort in acquiring, validating and distributing elicited knowledge to its so-called Community of Practice, a cross-organisational network with over 4,000 members. IBM's interest is in the effective distribution of information, and tacit and explicit knowledge, and experiences and ideas that are structured in such a manner as to encourage exchange and re-use.

IBM's ICM knowledge management software tool supports the transformation of individuals associated with certain phrases, key words, skills, etc. This process is manual and costly, as it requires the time of a human expert in terms of reading contributions, assisting the contributors as

well as servicing the database. Non-the-less of great value as the knowledge collected is of high quality. Alternative solutions exist that allow knowledge management systems to automatically identify valuable and relevant knowledge. Such a system is Casmir's Learning Engine (CLE) a system developed round proprietary neural network technologies (www.casmir.net).

2.2 HANDLING AND VISUALISING KNOWLEDGE

Knowledge management is concerned with the identification, encapsulation, and redeployment of knowledge at the workshop, operational, and designer level. The process requires for the design and development of knowledge models, knowledge representations and best practices. Support tools need to be developed and deployed to assist in the search for knowledge, its visualisation and effective navigation in an effort to reduce the number of redundant searches. The overall goal is to make users of such systems more effective in their information management and communication tasks where learning times are reduced, knowledge is retained, and personal satisfaction and performance are increased thus benefiting the enterprise.

According to Kluge et al. (2001), knowledge is the understanding of relations and casualties, and is therefore essential in making operations effective, building business processes, or predicting the outcomes of business models. They also differentiate between explicit knowledge (knowledge that can be structured and documented) and tacit knowledge (knowledge linked to human senses and experience). They do however acknowledge that the two categories are heavily interlinked and near impossible to separate in practice as for example the comprehension of a written document (explicit knowledge) may require a degree of experience (tacit knowledge). They finally perceive knowledge in terms of relationships rather than databases. Thus the accumulation and storing of information coupled with an ability to create, effectively visualise and identify relationships between these items of information is considered a vital part in the success of a knowledge management software system regardless of the of the industry that it serves.

3. Information Visualisation

According to Tufte (1994), the world is complex, dynamic, multidimensional; the paper is static and flat. He also poses the question "How are we to represent the rich and visual world of experience and measurement on mere flatland?" Representations of data beyond the textual can be employed to make information more accessible and to detect patterns

and relationships as in C. J. Minard's (1781-1870) graphical narrative of Napoleon's army and its terrible fate in Russia. Different variables are plotted on a two-dimensional surface, army size, direction of movement, temperature, location, date and battle events. Researchers at Carnegie Mellon University employed SAGE (Chuah et al., 1995) an information visualisation system, using Minard's original data. Their efforts revealed details and relationships beyond Minard's original graphic showing that information visualisation is an effective tool for conveying complex ideas.

The rapid advancement and adoption of information visualisation in different areas is currently challenging system designers to find out strategies and tools to effectively discover, visualise and share particular types of information. Most common approaches include cone trees and tree structures as well new alternatives such as networked structures, hyperbolic views, trajectory and feature maps. All these concepts show marked diversity and tend to be used depending on the type of data and user requirements (Chen, 1999). Undirected graphs were chosen to represent the stored knowledge and its relationships despite the challenges they pose. The most popular algorithm for drawing undirected graphs was introduced by Eades (1984). It is referred to as the spring-embedder model and follows two aesthetic criteria: uniform edge lengths and symmetry. Subsequent research includes works from Kamada and Kawai (1989) Frutcherman and Reingold (1991) and Davidson and Harel (1996).

4. A Universal Tool for the Dissemination of Knowledge

The most common type of digitally stored information and knowledge exists in textual form where graphical and other representations are usually associated with sections of text. Current search engines are considered to be analytical, methodical, serial technologies suited to the activity of the left hemisphere of the brain where shapes and patterns that would tap in the right hemisphere have generally been neglected. It is suggested that by investigating the semantics of data links**,** classifications can be created regardless of physical boundaries. In turn these semantic connections can be given graphical form presented through a computer-based interactive graphic that improves cognition, reveals hidden relationships and enhances navigation.

4.1 A KNOWLEDGE MANAGEMENT TOOL FOR CAD

The project aimed to create a software tool that would assist users of CAD systems and students during the design process by taking advantage of accumulated knowledge. Useful Information stored within the databases

would consist of text, graphics, video-clips, pointers to executable procedures and valuable external resources including references and sources on the Internet. It was important that a general structure and sets of relationships in terms of links were defined between the various imported elements stored in the databases, this was essential for the delivery of a useful and coherent system that was easy to use and navigate. For example, if a CAD user initiated a query about constructing a cog-wheel, the system was expected to automatically produce the required information consisting of a series of operations that would lead to the construction of a cog-wheel as well as other relevant material. This would point experienced and non-experienced users to information that would satisfy their query with an option to investigate further depending on a user's further needs.

Thus the need of being able to update the system and service the links effectively and within a reasonable amount of time would add to the usefulness and long life of the system. As new information was added and old information was deleted the prospect of redundant or broken links combined with the considerable effort required to link new information to old records became a main concern. The obvious problem was related to swiftly and effectively navigating the extracted knowledge and updating and servicing the proposed databases. Thus a system was designed to provide for the automatic generation of relationships between elements of information stored within the databases.

4.2 THE PROTOTYPE SYSTEM

A prototype system was designed consisting of a database, a knowledge-retrieving mechanism and a dynamic relationship generator. A simple text-based interface was also provided to test the system. To test the system**,** the glossary pages 122-125 from D. J. Bowman's book, The CAD/CAM Primer (8,000 words) was used as a pilot text for applying the knowledge retrieval algorithms. One hundred and thirty glossary terms and the text accompanying them were used to create eighty-eight database records containing this information. To increase efficiency and assist the knowledge retrieving mechanisms**,** a mirror database was created where words within records were first tokenised. Subsequently their inverse frequencies ($1/f$ and $1/f^2$) were calculated and stored in the mirror database. Tokens with high frequencies were not included in the new database as their presence adversely affects knowledge extraction operations. Suppose that k (where k=14) filtered tokens were found within a knowledge base of n records (where n=8). Vectors ($SVector_n$) showing tokens present in each record are first generated for all records and stored in a database, i.e.

SV_1 = (0,0,0,1,0,0,1,0,0,0,0,0,1,1) … SV_9 = (1,0,0,0,1,0,0,1,1,0,0,0,0,1) → where 1 means a token is present, 0 when not

The SVector identifies content and requires minimum computation. Subsequently it can be used for *screening* purposes as it facilitates fast movement between relevant concepts stored within the knowledge base. A different vector (IdVector) that introduces context uses frequency to achieve more accurate results, i.e.

$IdVector_n$ = ((ts_1 * $idvt_1$), (ts_1 * $idvt_2$), … , (ts_{12} * $idvt_{12}$)), where: ts = attribute state (1 present, 0 not present),

idvt = identification value = (1/frequency) or ($1/frequency^2$)

The IdVector is used to calculate the knowledge weighing value of a record depending on filtered tokens being present, i.e.

$WRecord_n$ = (ts_1 * $idvt_1$) + (ts_1 * $idvt_2$) + …+ (ts_{12} * $idvt_{12}$)

Suppose the user made a query that when tokenised and filtered produced the following vector:

SV_0 = (1,1,1,0,0,1,0,1,1,1,0,1,0,0) → query vector

$Svectror_1$, the user query vector, is logically ANDed with SVector 1 – 9 for possible matches, i.e.

$SVector_0$ AND $SVector_1$ → not applicable

$SVector_0$ AND $SVector_2$ = (10100100100100)→ matches = 5, etc.

Records that have shown matches are ranked in terms of relevance dependent on the number of matches, in this case the *stack* looks like: 2, 4, 7, 5, 8, 9, 3, 6. However this simplistic mechanism does not work well and produces poor results, thus weighing factors need to be calculated for each of the records in the database in relation to the user query vector $SVector_0$. Subjective tests on users have shown that records with higher weighing values are most relevant to the user query and generally satisfy them. Calculating weights for all Sector quantities excluding $SVector_1$ that scored 0 matches are as follows:

$WRecord_2$ = 752.24, $WRecord_3$ = 427.70, $WRecord_4$ = 838.36, etc.

The new stack now looks as follows: 9, 4, 7, 2, 5, 3, 8, and 6. The new records will satisfy user queries a great degree better. When considering systems containing great numbers of records a further requirement arises. Assuming the system returned a finite number of records satisfying the user query how can the system ensure that these records do not to a great degree duplicate each other and that records with lower weighing scores are not excluded as they may contain useful information not present in the records high on the stack? Using the previous example let us assume that the system always presented the user with the top three records after a query was made, i.e. 9, 4, 7. The statement below refers to aspects of knowledge that the three stacked records, 9, 4 and 7 would cover if they were all read by the user, i.e. $SVector_9$ OR $SVector_4$ OR $SVector_7$ = (1,1,0,0,1,1,1,1,1,1,0,1,0,1)

The next statement refers to the common aspects covered by the three records on top of the stack compared to those found in the user query.

$SVector_9$ OR $SVector_4$ OR $SVector_7$ AND SVector0= (1,1,0,0,0,1,0,1,1,1,0,1,0,0)

Seven matches exist out of possible eight. A high score means that in terms of content records put forward by the system cover most topics within the query. A low score means that different records should be considered by the system lower on the stack. The above mechanisms also allow for the automatic creation of relationships between records and enable quick navigation between comparable concepts stored within the databases. To create such links dynamically all or subsets of selected records need to be considered against each other using the previous methods. The second phase of this research involves the development of a system that imports a database of over 12,000 records containing text (100-1,000 words per record), graphics, video clips, animations and other data items. A graphical interface based on unstructured graph technology will be introduced to enable fast and effective navigation.

5. Conclusion

This paper has outlined an original approach for the design and development of a universal information/knowledge visualisation tool and has outlined the mechanics that enable the working prototype. Of greater value is the ability of the system to automatically perform effective searches, identify and elicit knowledge, and automatically draw associations between concepts stored within unstructured databases. Its dynamic nature allows for the editing of

the underlying databases with minimum effort without any concern of broken or redundant links as they are dynamically allocated by the system.

References

Chen, C.: 1999, *Information Visualisation and Virtual Environments*, Springer.

Chuah, M. C., Roth, S. F., Kolojejchick, J., Mattis, J. and Juarez, O.: 1995, SageBook: Searching data-graphics by content. *Proceedings of CHI* , ACM Press.

Czerniawska, F. and Potter, G.: 2001, *Business in a Virtual World*, Ichor Business Books (Purdue University Press).

Davidson, R. and Harel D.: 1996, Drawing Graphs nicely Using Simulated Annealing. *ACM Transactions on Graphics*, 15(4):301-331

Eades. P.: 1984, A Heuristic for Graph Drawing. *Congressus Numeratium*, 42:149-160.

Frutcherman, T. M. J. and Reingold, E. M.: 1991, Graph Drawing by Force Directed Placement. *Software – Practice and Experience*, 21:1129-1164.

Heisig, P. and Vorbeck, J.: 2001, *Knowledge Management: Best Practices in Europe*. Mertins, K., Heisig, P., Vorbeck, J. (eds), Springer.

Kamada, T. and Kawai, S.: 1989, An Algorithm for Drawing General Undirected Graphs. *Information Processing Letters*, 31(1):7-15.

Kluge, J., Stein, W. and Licht, T.: 2001, *Knowledge Unplugged*, Palgrave.

Tufte, E. R.: 1994, *Envisioning Information*, Graphics Press.

Tufte, E. R.: 1995, *The Visual Display of Quantitative Information*, Graphics Press.

INTERACTION AND SOCIAL ISSUES IN A HUMAN-CENTERED REACTIVE ENVIRONMENT

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Abstract. In the last decade, the ubiquitous computing paradigm has pushed computation out of desktop and made computational services pervasive throughout a physical environment. In this paper, we describe the work in progress in developing ubiquitous/pervasive applications supporting digital design media presentation. The result of the experimental study in various spatial settings is reported. Finally, we present a model of interaction towards a human-centered reactive environment, and discuss some interaction and social issues that must be addressed in implementation.

1. Introduction

As ubiquitous computing (Weiser, 1991) provides new ways of manifesting computation in the physical world, the style of interaction is moving beyond the desktop and into architectural space where we live and act. A new paradigm for multi-user multi-modal interactions in an integrated space is emerging, based on several related research such as "cooperative buildings" (Streitz et al., 1998), "tangible interface" (Ishii, 1997), "augmented reality" (Buxton, 1997), "wearable computers" (Bass et al., 1997), and so on. It is also recognized that the conventional model of interaction will have to evolve towards human-centered interaction (Dertouzos, 2001).

Interacting with computation opens up a new set of research issues in an integrated design of physical and virtual worlds. This paper describes the work in progress in developing ubiquitous/pervasive applications supporting digital design media presentation. The result of the experimental study in various spatial settings is reported. Subsequent sections provide a model of interaction towards a human-centered reactive environment, and discuss some interaction and social issues that must be addressed in implementation.

2. The I^3 Environment

Our research group in Information Architecture at National Cheng Kung university in Taiwan is developing "the I^3 environment" (**I**ntelligent, **I**nteractive, and **I**nformative) based on an integrated design of physical and virtual spaces. We have installed a variety of touch-sensitive displays and computational devices in a physical environment, including large-display interactive whiteboards, touch-sensitive tabletop, tablet computers, PDAs, and other environmental sensors. We are motivated to re-design a hallway supporting digital design media presentation, informal group discussion, and asynchronous multimedia annotation.

In order to get this research work in practice, we begin with the development of Tangible Media for presentation and exhibition of digital design studio work. An experimental study was performed by placing a wall-sized interactive whiteboard, an interactive electronic table, along with cameras and VCRs into the hallway. The setting allows students to draw annotations on wall-sized displays and interact with other digital equivalents using fingers, electronic pens, and voices when they engaged in design jury activities in a digital design studio.



Figure 1. The prototype of the I^3 environment includes iTable (on the left), Tangible Media (in the middle), and Intelligent Corner (on the right).

For the purposes of illustration in this paper, we will discuss a small subset of the capabilities of the I^3 environment, in a scenario of students in a digital design studio, presenting and exhibiting their work in the hallway. Here we list three key components that have been implemented in the I^3 environment, as shown in Figure 1.

1. *iTable* is an interactive electronic table that contains a touch-sensitive display surface and a built-in computational device coupling with a palm-sized physical building model. The iTable is placed in a public space for display, communication, and annotation of students' design work. People can write and draw on the display surface with a pen and interact via finger with digital information. The physical model is useful for directly controlling the perspective viewpoint of digital

three-dimensional models. Moving the physical model correspondingly alters the orientation of perspective geometry.

2. *Tangible Media* provide multiple touch-sensitive monitors and an optical device, pointing the user's current location on a paper-based floor plan. The display is bound to the movement of the pointer device. Relocating the pointer to a new position correspondingly resets the view of a virtual space. As the user touches a virtual space on the first monitor, digital information is conveyed from one monitor to another, triggering a built-in walk-through animation to be displayed on the second monitor. The objective is to examine how people deal with information with multiple views in a same display space.
3. *Intelligent Corner* is a project for presentation and dynamic exhibition of digital design studio work in an integrated space. In our initial prototype, two large wall-sized interactive whiteboards are mounted in parallel. An iTable is placed in a corner of the corridor. The whiteboards simultaneously display different views of design, such as design plan, perspective, and three-dimensional animation. As the user clicks the electronic pen over the first interactive whiteboard, it triggers an internal operation that activates playback of a multimedia movie in the second whiteboard accordingly. We attempt to explore a particular style of human-centered multi-modal interaction in an integrated space as input channels, and develop physical representation for output channels of digital information. The objective is to develop a reactive environment with a certain degree of ubiquity, tangibility, and in particular, context awareness.

iTable, *Tangible Media*, and *Intelligent Corner* are a sequence of increasingly developed systems for the I^3 environment, moving towards human-centered interaction. Rather than conceiving of interactive systems as a network of computational devices, we take a human-centered approach to developing a reactive environment supporting digital design media presentation. There may be a variety of approaches to developing reactive environments [Cooperstock, et al., 1997], but we will focus on the interaction and social issues based on an integrated design of physical and virtual spaces.

3. Human-Centered Interaction Model

Having briefly outlined the components of the I^3 environment, we can see an emerging model of human-centered interaction for characterizing an integrated space. An integrated space has three fundamental levels of abstraction: *cognitive space, physical space,* and *virtual space*. Here we

identify some key characteristics generally applied to an integrated space, as illustrated in Figure 2.

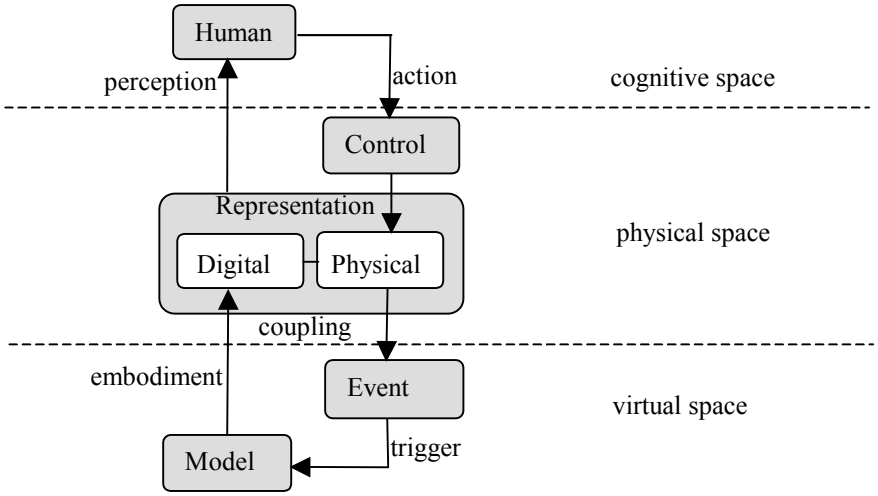


Figure 2. A model of human-centered interaction supporting reactive environments

The human-centered interaction model being proposed here is based on five key elements of interactive systems: *human, control, representation, event,* and *model*. In a reactive environment, human can be considered as an entity without independent sets of input and output channels. There are two fundamental levels of representation: *physical* representation and *digital* representation. Human perception comes from physical representation coupling with the state of digital representation. Underlying digital representation are digital models that map onto physical representation in varied application domains. Physical representation is perceptually coupled to digital representation of digital models. Changing the physical representation triggers an event, yielding digital representation that is computationally mediated.

Physical representation embodies interaction with digital information, making computation ubiquitous, yet invisible. For example, the iTable serves as a computational artifact with physical representation and control for direct manipulation of underlying digital 3D models. The iTable also uses a physical building model as physical representation of an actual building. Moving or rotating the physical building model (i.e. physical representation) changes the perspective geometry (i.e. the digital representation) of a virtual space (i.e. digital models).

4. Interaction and Social Issues

Having established a human-centered interaction model, we can now further discuss some research issues in accordance with interaction and social perspective. We set out to identify a set of research issues based on the implementation of the I^3 environment. Those issues include *human factors, embodiment, coupling, ontology, metaphors, media space,* and *context awareness*.

Issue 1: Human factors

While the ubiquitous/pervasive computing technology is truly promising, we believe that this approach will succeed only if we take into account the human factors governing the use of these systems. Our study shows that a reactive environment demands new interaction techniques to cope with human factors. For example, "pull-down menus" in a wall-sized large display are hardly to reach especially for a short person. We often re-configure the boundary of the display area in order to cope with different scale of human body. "Drag-and-Drop" user interface cannot be used effectively because few people have been able to touch multiple "windows" by standing at the same physical location.

Cognition is another human factor that demands careful consideration. To some degree the user's focus on a wall-sized display is *episodic* because he/she is often engaged in a conversation with other people in public space. The user does not have additional cognitive capacity to detect slight change in a single large display, not to mention to perceive simultaneous changes in multiple large displays.

There are some other social interaction issues to be addressed. Synchronization is a problem in the development of Intelligent Corner when many people want to make annotations on the same drawing. In a physical space, two people are hardly able to write in the same area at the same time. One may unconsciously block part of the display. It would be also useful to support awareness of external events occurred in some other spaces. However, information overload is a major concern. We need an efficient way to partition a media display space supporting peripheral awareness.

Issue 2: Embodiment

The second issue is embodying the control and representational aspect of tangible interfaces. From a design viewpoint, it is appropriate to question what makes for good tangible interface design. Most tangible interfaces are so far developed by technological practices. Many practices are driven by the availability of sensor technology and the emergence of new control devices. Due to the lack of theory in understanding of physicality in interaction, new forms of tangible interfaces rely on system designers'

experiences of an interaction system. It is needed to uncover the philosophical assumptions that run throughout engaged practices of embodied technology, so that we can understand more about what kind of physical representation can be made for tangible interface. A foundational study of embodied interaction is provided in (Dourish, 2001).

Issue 3: Coupling

Another important issue is coupling physical artifacts with digital information. To develop tangible interface, physical artifacts must be *statically* coupled with or *dynamically* bound to digital information. As illustrated in the I^3 environment, the iTable affords a variety of association relationships between physical artifacts and digital information. In the Intelligent Corner, the user is presented within a reactive environment where he/she can manipulate digital information through a chain of remote action. A local action on the iTable can have a remote effect through a sequence of couplings, including associations of digital media and physical properties. By coupling, we can build up and maintain association relationships between digital and physical representations.

Issue 4: Ontology

Ontology is concerned with the nature of existence and relations between computational artifacts. We use ontology to refer to a user's cognitive model. Ontology provides the structure from which meaning can be constructed. In the Intelligent Corner, for example, different modes of interaction and settings of practices (e.g. digital media presentation) will result in different ways of understanding the ontology of a reactive environment. If we look at Tangible Media, the user moves his/her arm along with a physical model to perceive the building's interior spatial extensity in a virtual form. The user perceives what he/she moves and interprets the meaning that may be conveyed though a sequence of image displays. Based on our observations, the user's action controls his/her perception in accordance with an ontological structure. On one hand, ontology is a *consequence* of interaction. The user's ontology arises from his/her engaged action in the physical world. On the other hand, ontology is an *internal phenomenon* created by the user of an interactive system. A reactive environment should provide a certain degree of flexibility in dealing with an evolving ontological structure, rather than statically embedded in some computational artifacts.

Issue 5: Metaphors

A new interaction metaphor is emerging in understanding an interactive space. Here we are not talking about "desktop", "menus", "dialogs" user interface metaphors in personal workstations. Rather we are concerned with

the use of the real world as a metaphor to conceive and interpret, and understand a reactive environment. For example, a metaphorical physical model in the iTable represents an actual building, which incorporates the sense of physical presence from the real world. We use the metaphorical model as a tangible interface for interaction. The Intelligent Corner is largely concerned with metaphorical physical properties (e.g. the iTables and interactive walls) for embodied interaction. Interaction metaphors can be used to extend the sense of familiarity into a broader range of embodied phenomena.

Issue 6: Space as Medium

As digital information takes physical form and is mapped onto artifacts, the distinction between physicality and virtuality is burring. Architectural space becomes a *medium* for interaction. To explore this idea, let us take the example of Intelligent Corner. A wall becomes a medium for the expression of digital information. The essence of Intelligent Corner is in the way in which digital information moves from one wall to another through social interaction in the presence of the iTable. An interactive wall must provide more functionality than a whiteboard. Taking a broader view, media space provides an opportunity to cut across conventional device boundaries and offers a way of interacting with our surroundings.

Issue 7: Context awareness

Context refers to *implicit* situational information embedded in computational devices for interaction. An interactive system is context-aware if it can interpret explicit acts and react to implicit situations or settings. Dey refers to context as any information that can be used to characterize the situation of a person, place, or an object between a user and an application (Dey, 2001). In a reactive environment, it is appropriate to question what sort of context in which an action may arise.

In a building space, however, context may change over time. A corridor is a walk-through space that might be occasionally used for design jury activities. Group discussion often occurs when people met in the corridor. Collaborative mark-up can be made in the course of discussion when interactive whiteboard is provided. An important aspect of context awareness is to take into account evolving contexts in a reactive environment, providing computational services that are appropriate to the particular user, situation, and spatial setting.

5. Conclusion

This paper sets out to identify a set of issues that are at work in some major components of our current research in an integrated design of physical and virtual spaces. We present several interactive prototype systems in terms of the implementation of the I^3 environment. In the light of these prototype investigations, we propose a human-centered interaction model in such a way to set out some basic foundations for emerging new forms of multi-user multi-modal interactions in the physical world.

Ubiquitous computing has encouraged us to explore various aspects of a reactive environment, incorporating tangible interfaces into architectural space and into fabric of work and design practice. The experimental study shows that research in developing interactive systems and a reactive environment is inherently empirical. It relies on a prototyping development cycle that can react to feedback from user evaluation. Future work is to develop perceptional capabilities through embodied interaction supporting context awareness in an integrated space, catching up to the vision of "*Form follows function. Function follows code*."(Mitchell, 1999).

References

Bass, L., Kasabach, C., Martin, R., Siewoirek, D., Smailagic, A., and Stivorik, J.: 1997, The Design of a Wearable Computer, *Proceedings of the CHI'97 Conference on Human Factors in Computing Systems*, pp. 139-146.

Buxton, W.: 1997, Living in Augmented Reality: Ubiquitous Media and Reactive Environments, *in* K. Finn, A. Sellen and S. Wilber (eds.), *Video Mediated Communication*, Hillsdale, N. J.: Erlbaum, pp. 363-384.

Cooperstock, J. R., Fels, S. S., Buxton, W., and Smith, K. C.: 1997, Reactive Environments, *Communication of The ACM*, September, Vol. 40, No. 9., pp. 65-73.

Dertouzos, M. L.: 2001, *The Unfinished Revolution: Human-Centered Computers and What They Can Do For Us*, HarperCollins Publishers, Inc., USA.

Dey, A. K.: 2001, Understanding and Using Context, *Personal and Ubiquitous Computing*, 5(1), pp. 4-7.

Dourish, P.: 2001, *Where the Action is: The Foundations of Embodied Interaction*, The MIT Press.

Ishii, H. and Ullmer, B.: 1997, Tangible Bits: Towards Seamless Interfaces between People, Bits, and Atoms, *Proceedings of the CHI'97 Conference on Human Factors in Computing Systems,* pp. 234-241.

Mitchell, W. J. (1999), *e-Topia*, MIT Press.

Streitz, N. A., Geiβler, J., Holmer, T.: 1998, Roomware for Cooperative Buildings: Integrated Design of Architectural Spaces and Information Spaces, *in* N. A. Streitz, S. Konomi, and H-J Burkhardt (eds), *Cooperative Buildings: Integrating Information, Organization, and Architecture*, *Proceedings of CoBuild'98*, Springer, pp. 4-21.

Weiser, M.: 1991, The Computer for the 21st Century, *Scientific American*, 265, September, pp. 94-104.

Research of the I^3 environment can be found at http://www.arch.ncku.edu.tw/ialab

AIDED DESIGN STRATEGY UNDER THE PROFESSIONAL KNOWLEDGE-ORIENTATION

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Abstract. Professional knowledge is a key component of the decision making process, as well as a major part of the thinking process. This research uses a strategy oriented by professional knowledge to assist the analysis of strategies in the design process, and to incite different design thinking under the operation models of media; through the basis of the design process, analyse the utilization of professional knowledge by designers in the design process and the different knowledge understanding methods under different media utilizations.

1. Introduction

The development of computer-aided design in construction has moved from the early stage representation of shapes to the present animated-simulation process, paying ever more attention to the design process and thinking of the designers. Systematically-organized complete databases of the professional knowledge required can now be made available through computers (Maher et al, 1995), and these allow designers to take appropriate design decisions, leaving them to spend more time on creative thinking. In the design process, designers may choose from many solutions available to solve a particular problem, and they may have a particular leaning or a particular area of consideration, ie a "design approaching strategy". Common "design approaching" strategies that can be found in the design process are form-oriented and function-oriented strategies. Gero(1996) pointed out that the design process can be seen as the designer using the professional skills in "micro strategies" to tackle design issues, and use "macro strategies" to consider the present situation, and the process in which the solutions are obtained is also a decision process. Schmitt(1994) believes that the main origins for a design with creativity are the differences in learning abilities and the way to utilize knowledge. By "utilize knowledge", the amount of knowledge in precedents utilized is considered paramount. Oxman(1994) asserted a design thinking based on design precedents, and search for

inspirations through studying precedents - such innovative ideas gleaned from precedents usually represents unexpected new ideas. Chen and Lee (2001) advocated a professional strategy oriented towards the “media”, with changes in the media influencing the design strategy and thinking models of the designer, and the orientation of the media changing the design strategy of the professionals. Therefore, the design knowledge rooted in the sketching drawn by the designers becomes the key towards the decisions made in the entire project. At the moment, there has been no research into a strategy oriented towards professional knowledge and its relationship with design thinking; media and thinking are key factors influencing the early-stage conceptual development in architectural design, and professional knowledge is a key factor influencing decisions, and hence a key factor in influencing thinking. The more areas considered by professional knowledge, whether more changes in media can assist the presentation of professional knowledge; different design strategies under different media, changes in the media changing design strategies; whether professional knowledge can change thinking methods resulting in different strategies; therefore this research’s questions are: under different design media environments, what are the differences in the effects of professional knowledge on the thinking and decisions of designers? Can orientation by professional knowledge assist the effective development thinking of designers? What type of professional knowledge and skills are required in using sketching? What are the relationships between media and sketching under different design strategies? This research uses a strategy oriented by professional knowledge to assist the analysis of strategies in the design process, and to incite different design thinking under the operation models of media; through the basis of the design process, analyse the utilization of professional knowledge by designers in the design process and the different knowledge understanding methods under different media utilizations.

2. The cognitive orientation to Design Media

The traditional design process has a complete, functional and formal structure: analysis, systems, assessment and appearance. The computerized design process does not possess such a functional structure. Hanna and Barber(2001) demonstrated through statistical analysis that, in sketching, design creativity and computer-aided design, using computer media design in the design process results in statistically-significant differences. According to the research of Bentley(1999), newly-developed CAD tools can inspire the creativity of designers, using dynamic changes to solve present issues and overcome the limits of traditional design tools. Suwa and Tversky divide the areas that designers see and pay attention to into four areas: depicted areas and their relationship with their sensitivities, specialties and spatial patterns, functional thought and knowledge. The former two categories supply with us tangible

information, while the latter two provide intangible information. However, functional thought and knowledge are the two key areas that orientate the spatial relationship (Kavakli and Gero, 2002). Sketches have another important characteristic. They do not give something tangible to the designer when the work starts; rather, it is something that is created at the first stage of the design process. Through writing down their thoughts and inspecting them, or through comparisons on the windows on the computers, designers can improve or build on their thinking and generate new characteristics or new links, and to continuously improve the sketches. Apart from sketches, Oxman (2000) stated that methods of presentation of knowledge are also important, and should be clearly communicated to the designer. In the described work, we experiment with the design media becoming a general representation that is operable in a special design environment. These general representations are usually formed on the basis of theoretical assumptions, and related to such assumptions is the psychological representation created by designers from their inner thoughts, and the strategy through which they externalize and operate on such representations.

3. Overview of Design Cognitive Strategies

Designers frequently utilize design strategies in a subconscious manner. In the hospital design example mentioned by Foque and Lammineur(1995), user interactions and computer-aided design methods were used to solve these issues. It also pointed out that a systematic method would not prevent or restrict the creativity of the designers. Kolodner(1996) pointed out that the heuristic strategies of strategic control play an indispensable role in the activities of creative design, including problem reformulation, emergence of properties and constraints on the solution, and to generate feedback from the environment, experience and experiments, and to merge prior designs into the present design. Candy(1998) espoused the objectives and methods in the presentation of strategic knowledge in design, especially the utilization of strategic knowledge by designers and the development of logical structure. Design understanding and the learning of knowledge recognition parameters can become part of design education (Oxman, 1999). Investigations into the ideas behind design thinking, knowledge structure, and design knowledge obtained through strategy can be used to benefit design education. Oxman(1999) also put forth the idea that computers is a media for the construction and testing the knowledge recognition process. In terms of design strategy, von der Weth(1999) analysed “step-oriented” and “function-oriented” modes. The strategies between “function-oriented” and “step-oriented” modes are different, as when sub-issues are treated thoroughly in the order of importance, from the clarification of the work to placing the sketches. The result of continuous work on sub-functions means that the solutions for sub-functions under consideration must result in adjustments towards other sub-functions that have undergone detailed planning. Through

immediately cementing the sub-areas, the use of “function-oriented” methods in the design process can significantly save time. However, it may result in the optimization of a solutions project becoming more complex. Another similar change-improvement method demonstrated is that during the research, those experienced designers without systematic design training favor “function-oriented” strategies (von der Weth, 1999). Also, Boulanger(2001) pointed out in the psychology and education areas, strategy is described through learning styles and personality types, rather than being a decision-making behavior.

4. Methodology and steps

The basic assumptions of this research are on whether using professional knowledge as an orientation will assist the development of the design thinking of designers. The subjects of the experiment are chosen to have professional design training and solid practical experience. The experiments are conducted in three stages: the first stage involves giving the subjects base maps and environmental and base restrictions, but no information related to professional knowledge. The second stage gives the subjects professional knowledge requirements; in terms of professional knowledge supplied, construction knowledge (such as structural systems), functional knowledge, knowledge on the materials, the environment, equipment and measurements are supplied primarily. In the third stage, detailed interviews are conducted. In terms of methodologies, “think aloud” is used; warm-up experiments are conducted prior to the actual experiments, and the topic of experiment is to design a museum to store an art collection, and the design development time is restricted to ten hours. There are three experiment groups: conventional media (group 1), the combination of conventional and computer media (group 3) and computer media (group 2).

4.1. DESCRIPTION OF THE DESIGN PROCESS

The environmental information given to the three groups of subjects involve the situation regarding the construction location, display methods, design targets, and the details of the design. The construction base is located in a large park, with several 8m-wide access ways, and 10m tall trees are planted alongside the access ways. The size of the construction site is about 100m x 100m, with the north and east sides facing open rolling grasslands, the west side facing dense plantations of 10m tall trees, and the south side facing 8m-wide roads and a plot of land reserved for a car park. The development strategy of the first group is to extend horizontally the perspective of the space at first, and to consider the window, balcony and horizontal shades (figure 1). Owing to the design habits of the subjects in group 2 and the requirements of this experiment, designing in group 2 was divided into two stages, firstly to develop the sketches on paper,

and secondly to develop the sketches on computers (figure 2). The subjects in group three started straight from computer media, and began with an analysis of the site and the horizontal extension of the construction (figure 3). An ellipsoid construction was designed to connect the three stories and the vertical dynamic lines, and the placement of escalators was used to consider the horizontal lines. Professional knowledge was also given for reference; when working on the restaurant, the needs of having a view and having "service" were considered, and it was decided for the service desk to be located in between the lift and the restaurant. The restaurant was placed next to areas with a better outside view, in order for guests to enjoy the views. Because the display area had plenty of walls, it was more closed to the outside world and as a result was placed in the northwest corner.

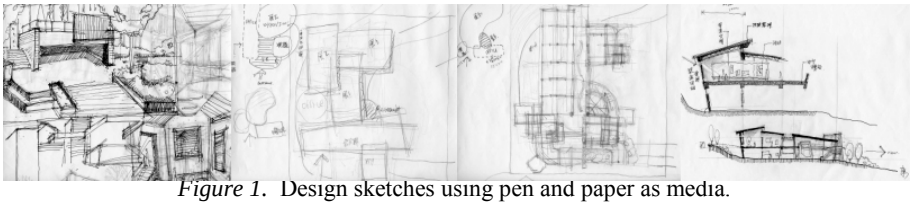


Figure 1. Design sketches using pen and paper as media.

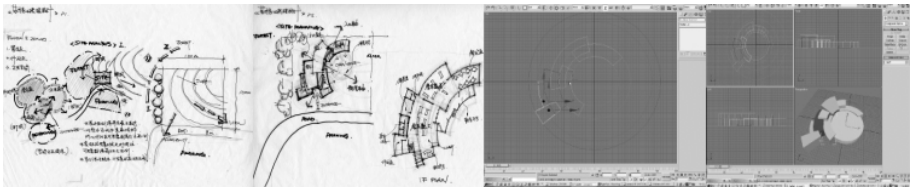


Figure 2. Idea sketches using traditional and computer media.

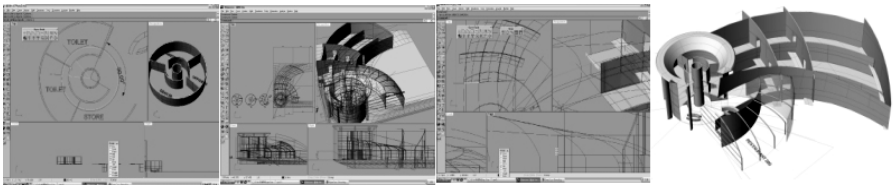


Figure 3. Idea sketches using computer media.

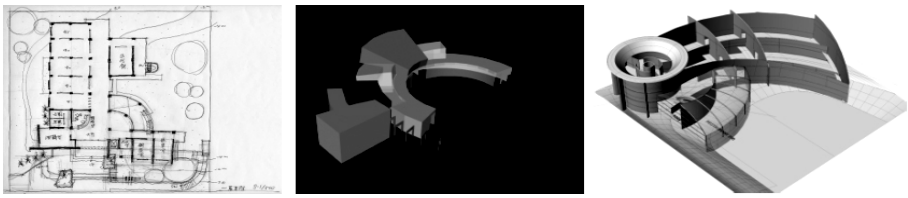


Figure 4. Idea sketches from the three groups of subjects; groups 1, 2 and 3.

4.2. PRESENTATION OF THE EXPERIMENTS' RESULTS

From presentations resulting from the three groups of subjects, the first group placed most emphasis on the floor plans of the floors, with the spatial placement and clarity in movement lines being paramount. Group 2 subjects eventually used computer models for presentation, to seek the relation between the space and the construction. Group 3 subjects, through computer models, demanded more presentation in the structure and the functionalities. (figure 4).

5. Discussion and analysis

5.1. COMPUTATIONAL SUPPORT FOR DECISION-MAKING

In all three groups, it is clear that the orientation of professional knowledge in design is intertwined with functionalities. By the second stage, after the designers obtained more information on the professional knowledge, it was filtered and selectively applied in the design process. Perspectives from experience played an important role. If the analysis and evaluation in the solutions process was incomplete and the conceptualization was not material enough, errors in the functions or common problems will appear at a later stage. Also, assessments tend to rely on areas chosen on a subjective basis, and cannot determine the overall requirements, similar to the issues described in Pahl and Frankenberger et al (1999). The ideas stage is where principles appropriate in the solutions are developed or identified, and the design is developed later. Through the three groups of experiments, the use of computer media to develop sketches allow, through accurate visualizations, effective concept decisions to be made, resulting in fewer post-decision changes on the concept compared to pen and paper sketches. Any changes are likely to be modifications as a result of conflicts between the structure and the modelling.

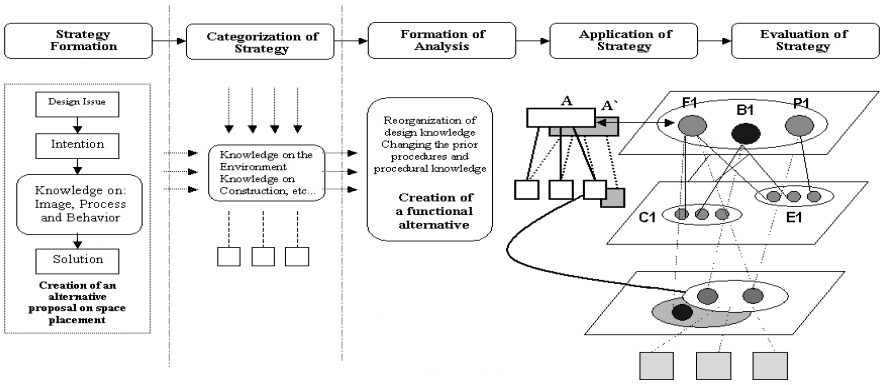


Figure 5. Flow Chart of Professional Knowledge and Design Strategy

5.2. PROFESSIONAL KNOWLEDGE-ORIENTATION AS A COGNITIVE MECHANISM IN DECISION -MAKING

Design thinking is the interactive process where design knowledge is used to resolve issues in design. Design knowledge can be divided into explicit and implicit knowledge: explicit knowledge includes knowledge on imaging, construction, functionality, materials, behaviour, etc.; implicit knowledge is similar to procedural knowledge, i.e., how to effectively utilize knowledge. In terms of the spatial design abilities, the utilization of professional knowledge and good interactions in design thinking can produce designs that suit the construction design requirements better; therefore, the analysis of the formation of strategy allows us to clearly understand the necessity of having prior training in order to run a design project: not only to improve the design to meet the design requirements, but also to improve the knowledge of designers and allow more accumulation of experience (figure 5).

5.3. DESIGN MEDIA FOR A COGNITIVELY BASED APPROACH

Design knowledge derived through experiments and observation is a major factor in the development of cognitive-based tools that can improve understanding and assist design (Oxman, 2000). Analysing the experiment shows that computer-aided design tools similar to traditional hand-drawings and sketches can assist in deeper thinking for designers. Various characteristics inspired by different media are like a strategy that subtly influences design thinking, understanding and decision-making.

6. Conclusion and future work

In terms of decision-making in design thinking, professional knowledge inspires strategies that change the design methods, and allow complex design issues to be clarified, while producing alternatives with more structure and functionality. A strategy oriented towards aiding professional knowledge can effectively assist designers to solve more sub-issues, and provide greater analysis into behaviour, process and imaging knowledge. In this research, the design strategy is the utilization of process knowledge, intertwined with construction and environmental knowledge. This research offers a staged guidance on the strategies of professional construction knowledge in architectural education, assisting designers' development in the design process and in the grooming of an architect, as well as inspiring the multi-dimensional considerations of the designer in the conceptualization and development stage. Given the huge amounts of experimental information, taking only one concept for analysis is the restriction placed on this research, and it has not been considered in this research whether a strategy based on an orientation of professional knowledge can inspire creativity, and whether it can emphasize the individuality of the exterior design -

issues that are appropriate for future continuing research.

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References

Bentley, P.: 1999, (ed) Evolutionary Design by Computers Morgan Kaufmann, San Francisco, CA.

Boulanger, S .: 2001, Multi-strategy workspace navigation for design education, *Design Studies,* 22(2), pp. 111-140.

Candy, L .: 1998, Representations of strategic knowledge in design, *Knowledge-Based Systems*, 11, pp. 379-390.

Chen, S. C. and Lee, J. Y.: 2001, A preliminary model of design thinking and creativity, *Stategic Knowldge and Concept Formation III '01*, Edited by John S Gero and Koichi Hori. Key Centre of Design Computing and Cognition University of Sydney, pp.227-246.

Gero, J. S. (1996). Advances in formal design methods for computer-aided design, *in* Gero, J. S. (ed.) *Advances in Formal Design Methods for CAD*, Chapman and Hall, London, pp. 293-298.

Hanna, R. & Barber. T.:2001, An inquiry into computers in design: attitude before-attitudes after. *Design Studies,* 22(3), pp. 255-281.

Kolodner, .: 1996, Powers of observation in creative design, *Design Studies*, 17(4), pp. 385-416.

Kavakli, M and Gero, J. S.: 2002, The structure of concurrent cognitive actions: A case study of novice and expert designers, *Design Studies*, 23(1), pp. 25-40.

Lloyd, P; Lawson, B; Scott, P.: 1995, Can concurrent verbalization reveal design cognition? *Design Studies*, 16(2), pp. 237-259.

Maher, M. L., Balachandran, M.B., Zhang, D.M. (1995) Case-based Reasoning in Design, Lawrence Erlbaum Associates, Inc.

Oxman, R.: 1994, Precedents in design: a computational model for organization of precedent knowledge, Design Studies, 15(2), pp.205-210.

Oxman, R.: 1999, Educating the designerly thinker, Design Studies, 20(2), pp.105-122.

Oxman, R.: 2000, Design media for the cognitive designer, Automation in Construction, 9(4), pp. 337-346.

Purcell, A. T. and J. S. Gero.: 1998, Drawings and the design process: A review of protocol studies in design and other disciplines and related research in cognitive psychology. *Design Studies,* 19(4), pp.389-430.

Pahl, G; Badke-Schaub, P. and Frankenberger, E.: 1999, Résumé of 12 years interdisciplinary empirical studies of engineering design in Germany, *Design Studies*, 20(5), pp.481-494.

Schmitt, G(1994) Case-based design and creativity, Automation Based Creative Design.

Suwa, M. & Tversky, B.: 1997, What do architects and students perceive in their design sketches? A protocol analysis. *Design Studies*, 18(4), pp.385-403.

Vor Der Weth, R.: 1999, Design instinct? the development of individual strategies, *Design Studies*, 20(5), pp. 453-463.

HOW TO SIMULATE AND REALIZE A DISAPPEARED CITY AND CITY LIFE?

A VR cave simulation

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Abstract. Computer simulation is used well in historical architecture restoration and research in a small scale for a long time, and should be used in a larger scale to represent a city, especially a disappeared city. Therefore how to utilize computers to coordinate both architectural and cultural data of a city becomes an important issue. This study takes Chang-an City that existed 1400 years ago but disappeared now as example and tries to develop a computerized and visualized method to simulate and realize a disappeared city and it's life. Finally, we represent simulations in a virtual reality cave (VR Cave) to make navigators evolving in and interacting with the virtual Chang-An City.

1.Introduction

Historically, architectural data, either eastern or western, are recorded in writing, drawing, pictures and models (Ma, 1984; Hsu, 1990; Lee, 1990; Liu, 1996). The content of these data included structure, form, scale and material of building (Fu, 1963; Guo, 1963; Lai, 1997). With respects to a historical city, the media of recording data was the same as stated above; however, the content had expanded from representing a single building to the city as a whole. Not only the design principles but also the social system, the cultural activities, and the city life at that time were recorded (Tatsuhiko, 1986, 1994, 1995, 1997, 1998). By means of these recorded data, we are able to restore the architecture and the city as well as the cultural activities

and the city life of that particular time.

Due to the limitation of conventional media, the architectural data was recorded incompletely (Chiu and Lan, 2001; Potier, 2001; Tang, 2001). Therefore, mistakes often occur in the restoration. To overcome these mistakes, lots of researchers then start using computer simulation to identify the problems of restoration previously and propose alternatives (Potier, 2000; Tang and Liu, 2001; Tang 2001). Potier(2000) established a computerized procedure of restoration, which utilized computers to restore historical remains. Using Potier's establishment as the base, Tang (2001) proceeded it to actual restoration project. The discovery was that 3D visualization could solve problems and conflicts that were raised by 2D drawing and perform a more accurate reasoning. Moreover, computer was used by Tang and Liu (2001) in more detail such as solving the visual disharmony of color and material for restoration.

2. Problem and Objective

Nowadays, computers are used in historical architecture restoration and research in a small scale. After we realize the characteristics and advantages of computers, we should use them in a larger scale to represent a city, especially a disappeared city. The restoration shall include architectural data such as palaces, blocks, markets, and streets as well as cultural activities such as dancing, singing, chess, and sports. Therefore the problem of this study is how to utilize computers to coordinate both architectural and cultural data of a city? The objective of this study is to develop a computerized and visualized method to simulate and realize a disappeared city and it's life.

3. Methodology and Steps

There are four steps in this study. First, we take Chang-An City that existed 1400 years ago but disappeared now as the example and obtained information from seven sources: archeological data, historical literature, relics, remains, wall paintings, stone inscriptions and new research findings. Second, we make computer models of static buildings and dynamic activities of Chang-an city. Third, we combine architectural and cultural data to product seven major simulation sets, including foreign diplomats entering Han-Yuang Palace, banquets in the Palace, ladies playing chess, polo game, drinking in Li-fun, camel caravans in the market, and trades in the market. Finally, simulation is represented through a virtual reality (VR) Cave in order to make navigators evolving in and interacting with the virtual Chang-

An City.

3.1. RELEVENT DATA OF CHANG-AN CITY

3.1.1 Architectural Data

After collecting plenty of data that were recorded by seven resources we mentioned above, we can not only outline the layout of Chang-An city but also realize the typical types of architecture. Generally illustrating, the form of Chang-An City is a rectangular which wide is 9 kilometers and length is 8 kilometers, and inside the rectangular was crossing street system (Figure 1). The street in the middle of the system is the main street, which wide is 155 meters and is called Chu-Chuai Street (Figure 1a1). Min-Da Gate locating at the south of Chu-Chuai Street is the main gate of the city (Figure 1a2). The blocks separated equally by crossing street system were the basic living units named Li-Fun (Figure 1b). Especially, two of these blocks mirroring by Chu-Chuai Street and called East Market (Figure 1c1) and West Market (Figure 1c2) are the main business sections of the city. The trapezium on the top of the rectangular area is Da-Min Palace where many palaces locate and the imperial family live (Figure 1d). In conclusion, gates, palaces, markets, and residences are the four typical types of architecture we want to discuss this time.

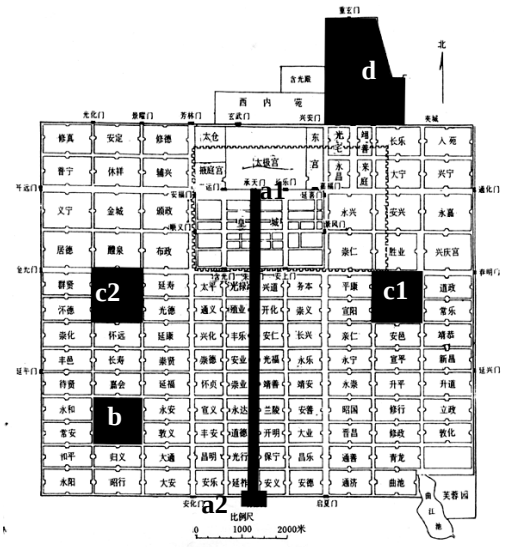
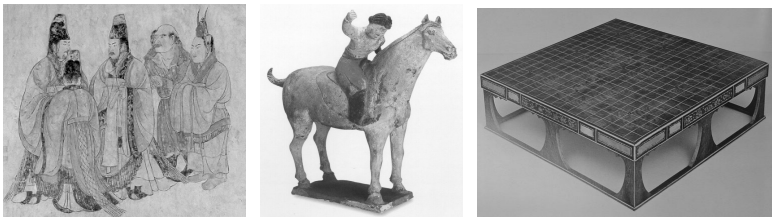


Figure 1. The plan of Chang-An City

3.1.2 Cultural Data

In addition to architectural data, we can also gather cultural data from collections of seven resources. In other words, besides typical types of architecture, we can also represent typical parts of city life in Tang dynasty by analyzing wall paintings, underground relics, and well-protected relics mainly. For example, the circumstances of foreign diplomats paying tribute (Figure 2a), ladies dancing, and banqueting are revealed by wall paintings in graves. Pottery figurines and golden implements that were stored underground show what the diet habits were and how people played polo (Figure 2b), which was the famous sport at that time. To deserve to be mentioned, plenty of well-protected relics, such as equipments of chess (Figure 2c), musical instruments and furniture that were presented to Japan by Tang dynasty 1400 years ago, also hint many activities in Chang-an City.



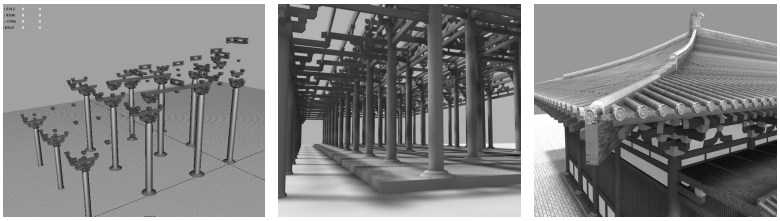
a b c

Figure 2. Cultural data: (a) Wall painting (b) underground relic (c) well-protected relic

3.2. COMPUTER MODELING AND REASONING

3.2.1 Architectural part

Although we have already analyzed the data we collected, and confirmed the typical types of architecture including their plans and sections. We still have to reason when we model them. Take Lin-Da Palace for example, measuring the remains, using the drawings that archeologists have already reasoned and surveying relevant research papers still can't support us to make a completed 3D model. We can only make a framework (Figure 3a) and indicate a basic form of it (Figure 3b). In order to make the model more detail, more data available are necessary. In other words, after collecting more relics such as tiles of roof and ground, observing buildings which imitate the style of Tang dynasty such as the detail of structure, and analyzing the color of building on several wall paints can make the model more real (Figure 3c).

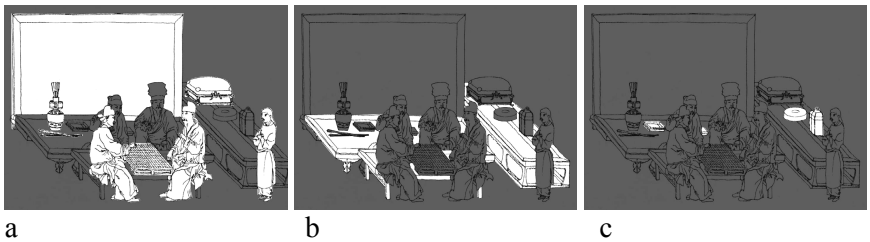


a b c

Figure 3. Computer model of Lin-Da Palace: (a) Framework model (b) Basic form model (c) Detail model

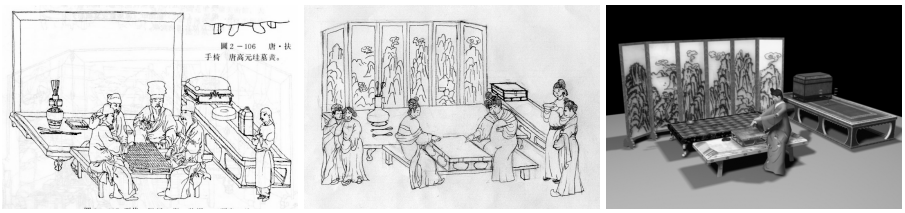
3.2.2 Cultural part

We are familiar with the process of making and reasoning architectural models but have no experiences of making and reasoning cultural models. In other words, the researchers of architectural fields neglect cultural activities of a space before, and need to propose an integrated method, which corresponds to the methodology of archeology and art history. After using this integrated method, we can combine data and reason results before making models. There are five steps of the process we proposed in this research. Take playing chess for example, we take a drawing which describe the scene of playing chess in Five dynasty as the base firstly (Figure 5a). Second, we start to replace implements of Five dynasty with those which also exist in Tang dynasty (Figure 4a). Third, we compose many parts of different implements when we discovered that the implements in Five dynasty are a little different from the ones in Tang dynasty (Figure 4b). Then we try to deal with surplus implements, which do not exist in Tang dynasty, by replacing anything suitable (Figure 4c). Finally, we draw a supposing drawing of the ladies playing chess (Figure 5b) and start to make computer model (Figure 5c).



a b c

Figure 4. The process of reasoning



a b c

Figure 5. The process of reasoning

3.3. DATA INTEGRATION

However, we have to combine architectural and cultural data to produce a completed representation of a city. Integrating the right places with the right activities is the most important thing. For example, ladies playing chess can happen not only in architectural interior but also outside of it. After surveying many data and discussing with experts, we put ladies playing chess in Lin-Da palace. Because many clues such as the kinds of implements, the arrangement of furniture, and clothing of people are all reveal the result. Finally, we integrate seven major simulation sets, including foreign diplomats entering Lin-Da Palace, banquets in the Palace, ladies playing chess, polo game, drinking in Li-fun, camel caravans in the market, and trades in the market (Table 1).

Table 1. The hierarchical data of virtual Chang-An City

	Architectural data	**Cultural data**
Virtual Chang-An City	Lin-Da Palace	Foreign diplomats entering Lin-Da Palace
		Banquets in the Palace
		Ladies playing chess
		Playing polo game
	Li-Fun	Drinking in Li-fun
	West Market	Camel caravans in the market
		Trades in the market
	Min-Da Gate	*Foreign diplomats entering
		*Camel caravans entering the market

3.4. VR CAVE REPRESENTATION

Representing in a VR Cave can make a simulation more real, because the surrounding screens can produce more sense of space than flat computer monitor (Figure 6). Furthermore, we also produce two frames with different view angles to be viewed separately by left and right eye, in order to increase the sense of space. Instead of viewing an animation, navigating in real-time render scenes and interacting with objects are also important issues to make people evolving in a virtual reality (Figure 7).

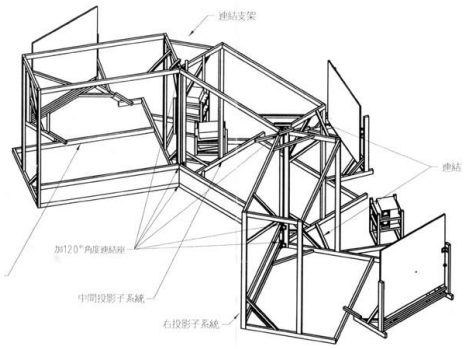


Figure 6. A virtual reality cave



Figure 7. A simulation in a VR Cave

4. Results

This study has found three phenomena. First, by means of this method of simulation and VR Cave representation, we successfully reconstruct the

architecture and cultural activities of Chang-An City in Tang Dynasty, which was approved by archeologists, art historians and architects. Second, by combining the research methodologies of archeology, art history and architectural restoration with computer technology, we provide archeology with a new direction of methodology. Third, by adding the social activities into the restoration of architecture, we are able to ask new questions that were not found before.

The significance of this study is to develop a computer simulation combining the research of archeology, art history and architecture. Because of the size of Chang-An city, this study focuses only on city gates, palaces, blocks, markets, streets and their inner activities. Extending to the whole city will be the future study.

References

Chiu, M.L. and Lan, J.H.: 2001, Discovery of historical Tainan: a digital approach, Automation in Construction 10, 355-364.

Hsu, M. F.: 1990, Traditional Craftsmen and Local Community: Hsin-pu Taiwan interpreting the socio-cultural role that traditional craftsmen played within a local community for building a house, Traditional Dwelling and Settlements: Working Paper, 20, 1–40, University of California, Berkeley.

Hsu, M. F.: 1992, The Impact of Japanese Colonization on the Traditional Tainan City, 1895-1945, Traditional Dwelling and Settlements: Working Papers, 47, University of California.

Liu, Y.T.: 1996, Understanding of architecture in the computer era, Hu Publish, Taipei.

Liu, Y.T.: 2001, The Hsinchu experience: a computerized procedure for visual impact analysis and assessment, Automation in Construction, 10(3), 337–343.

Lee, C.L.: 1990, The technology of historical architecture in Taiwan, Collection of papers on Restoration Techniques for Historical Sites, 50–61.

Ma, B.: 1984, Timber Construction Technology of Chinese Ancient Architecture (in Chinese), Science Press, Beijing.

Potier, S.: 2000, Computer graphics: assistance for archaeological hypotheses. Automation in Construction, 9(1), 117–128.

Rumelhart, D.E.: 1985, Notes on a schema for stories, Representation and Understanding: Studies in Cognitive Science, D.G. Bobrow □A.M. Collins (Eds.), New York: Academic Press.

Tang, S.K.: 2001, A study of the computerized procedure in the restoration of historical architecture, Thesis of master degree, IAA NCTU.

Tang, S.K. and Liu, Y.T.: 2001, The visual harmony between new and old materials in the restoration of historical architecture, CADDRIA 2001, 205-210.

Wu, C. and Zhang, H.: 2001, CAD system for Chinese traditional architecture, CADDRIA 2001, 331-335.

VIRTUAL REALITY IN ARCHITECTURE: ENABLING POSSIBILITIES

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Abstract. This paper examines the potential of Virtual Reality (VR) technologies for architectural applications. There has been a great deal of anticipation for its implications for architecture since Ivan Sutherland's first VR system in the 60's. The term VR was formalized and became popular in the main stream in the late 80's and became an industry by the late 90's. Although it has found good applications in Medicine, Flight Simulation, and Video Game Industry, its effect on architecture remains imperceptible. In the work that we review, we found that the success of VR in architecture has primarily been in the passive and exploratory applications. We also note that at the present time, the cost of VR systems is directly proportionate to the level of photorealism and immersion. We contend that photorealistic visualization and total immersion are not absolute prerequisites for making most design decisions. Hence, through this paper we bring to light the inherent promise of VR technology and the potential impact it could have with its current limitations, on the way we conventionally think and design our built environment pushing it beyond space and time constraints.

1. Introduction

What is VR?

The term Virtual Reality (VR) was coined in 1989 by Jaron Lanier of VPL research, to distinguish between the immersive digital worlds that he was trying to create and traditional computer simulations (Pimentel, 1995). For the purposes of this paper, we find Lingard's (1995) classification of VR as passive, exploratory, and immersive to be appropriate. Passive VR refers to such spectator activities as watching TV, seeing movies, reading books etc. Exploratory VR involves interactively exploring a 3D environment solely through the monitor of a computer. Examples include games like Myst, VRML architectural walk-through simulation etc. "Immersive VR (IVR) is the classic stage of VR, where the user can fully interact with the artificial environment, is provided stimulation for all the senses, and have their actions directly affect the computer generated environment" (Lingard, 1995).

1.1 WHAT IS ITS RELEVANCE TO ARCHITECTURE?

Ever since Ivan Sutherland developed (with support from ARPA) the first surprisingly advanced VR system during late sixties (Negroponte, 1993), there have been high expectations for the implications of this discovery for architects. For example, in 1968 Coons stated in his New York Times interview, "In a few years from now you (a group of architects) will be able to walk into a room and move your hand and have a plane or surface appear before you in light. You will be able to build a building in light so that you can walk around it and change it" (Herzberg, 1968). Van Dam (2000), a notable pioneer of computer graphics, observes that VR would offer a natural interface for architects to navigate through, make spatial judgements in, and manipulate three-dimensional physical environment. Thence, there is a good reason to be optimistic about its applicability to architecture.

In this paper we examine the current state of VR in architecture. We seek to understand if we have harnessed VR in Architecture by finding significant applications for daily productive use. We examine if VR has “enabled new possibilities” or “added value to the existing possibilities” in architecture.

2. Virtual Reality in Architecture

Although the term VR has a broader connotation, first image that comes to most people’s mind is probably that of an alien-like humanoid wearing a Head Mounted Display (HMD) tethered by cables and completely immersed in a fantasy world. Total immersion, photorealism, and real-time

interactivity have been the Holy Grail of VR research community. Unfortunately, the technology is not even close to achieving these for practical purposes.

To understand if VR technologies have "enabled new possibilities" or "added value to existing possibilities" in architecture we conducted a literature survey as a methodology to find where the working VR systems are, if any, in the field of architecture. We used *Copernic 2001 Basic* and *northernlight.com* search engines for finding information on the web. We critically studied several magazine articles, conference papers, journal articles, scholarly essays, and books on VR. In analyzing the use of VR in architecture, and to understand the "enabling" aspect, we sought architectural design or products that were not possible any other way; and to perceive the "added value" aspect, we expected to see increased efficiency in daily productive use.

We considered the potential of Head-Mounted Displays (HMD), Computer AudioVisual Environment (CAVE) technologies, Single Wall Projection Displays / Power Walls, WorkBenches, Fish Tank VRs and WIMPs (windows, icons, menus, pointing) listed in the descending level of immersion for possible practical applications in the practice and education of architecture.

2.1 WHERE WE ARE SUPPOSED TO BE

In 1993, Negroponte expected that "within the next five years more than one in ten people will wear head-mounted computer displays while travelling in buses, trains, and planes" (Negroponte, 1993). In 1994, Bar-Zeev and Jacobson predicted that "some time towards the end of the 1990s, clients and regulators could join architects in the Virtual Design Environment (VDE) to evaluate design and constructions prior to the actual laying of the foundation" (Bar-Zeev and Jacobson, 1994).

2.2 WHERE ARE WE?

In our research and analysis of relevant work in progress at selected US research universities, we note the following trends in the use of VR for: (i) walkthroughs for visualization, analytical simulation (e.g. energy, circulation, facilities management) and virtual reconstruction; (ii) design decision making;(iii) collaboration;(iv) marketing;and (v) construction.

We found architectural walk-throughs and distant collaboration to be the most widespread productive use of VR which are however limited to *passive* and *exploratory* VR. Most of the IVR projects we reviewed were done in the mid-nineties and they seem to have been either halted or spun-off into another application area. Beyond a few demonstration prototype IVR

systems in select research facilities, we did not find any systems in daily use in architecture or efficient enough for practical use. Our findings are consistent with Brooks' report on the state of IVR (Brooks, 1999). Brooks estimates that there are about a hundred installations in daily productive use worldwide, mostly in entertainment and vehicle simulations.

Table 1. Table summarizing architectural applications of VR in the US as we found in our survey (Appendix A). The numbers in parentheses refer to the listing in the Appendix. The costs of the systems are our best guesses based on product information we found on the web.

		HMD	CAVE	Power wall	Work-bench	Fishtank VR	WIMPy VR
Applications	Cost in $	.4–90K	295K–	1–200K	70K–	10K–	3K–
	Walkthrough	(7)	(6), (11)	(6)	(10)	(2)	(2), (11), (4)
	Design	(8)	(12)		(10)		
	Collaboration			(5)			(1)
	Marketing	(3)		(3)			(3)
	Construction	(9)					

2.3 WHY ARE WE NOT THERE YET?

Andreas Van Dam's (2000) comprehensive progress report on the state of VR technologies identifies the major bottlenecks and hurdles that need to be overcome. "Immersive Virtual Reality is still in an early stage of development, due to significant deficiencies on many fronts, including input and output hardware performance and ergonomics, interaction techniques, application software, development environments, cost, and reliability" (Van Dam, 2000).

Bill Hibbard (2000), a visualization expert at National Center for Supercomputing Applications (NCSA) in University of Illinois at Urbana Champaign observes that the three conditions that need to change before IVR can become widely used are the high cost factor, the apparent latency in tracking and user intrusive equipments. Polly Baker (2000), an NCSA CAVE expert, agrees that to justify the research work being conducted on CAVE, a million dollar installation, the factors laid down by Bill Hibbard needs to be resolved first. Having realized this, they are now experimenting with designing more economic and smaller footprints of CAVE like VR installations that are less immersive, easy to use and suitable for workspace

environments in terms of size and cost.

Until IVR systems become affordable, dependable, and offer high value over alternative approaches we do not foresee their widespread application in architecture. Even after this happens, appropriate application software for architectural design and interoperability will be the next big issues to be resolved before VR systems can become design tools. Until then, we have to contend with *passive* and *exploratory* VR systems, which we found in our study to be becoming increasingly popular in daily productive use.

2.4 WHAT CAN BE DONE TODAY?

At the present time, the cost of the VR systems is directly proportionate to the level of photorealism and immersion. Costs of a sophisticated VR system with a high degree of photorealism and immersion are not yet practical for use in architecture. If we remove these aspects which we contend are not absolute prerequisites for making most design decisions, real time interactivity becomes achievable which we argue to be more beneficial.

In the virtual wheelchair project (Appendix A, 2) navigability of the space was a chief concern, hence real-time interactivity being more important than photorealism and immersion. Several simulation projects of this nature are being carried to make design decisions based on temperature, humidity, air-flow and lighting simulation of spaces in buildings. Design evaluation using the three-dimensional interactive interface on a WIMPy VR proves to be more effective than looking at regular two-dimensional drawings. Reconstruction of demolished or inaccessible or preserved archeological sites is another noteworthy walkthrough application of VR in architecture. The Temenos project (Appendix A, 11) uses VR to provide a more precise and efficient means of acquiring valuable insight into the project for the students, scholars and others interested, which may not be possible through traditional means of representation alone.

The GreenSpace II project at HIT Lab at University of Washington (Appendix A, 1) applies the concept of distributed VR (distant participants present in shared virtual environment) to architectural design, facilitating a remote discussion of the architectural space. Projects like this are proving to be a great asset in getting one's ideas and thoughts across to the service consultants, most of whom are not trained to think spatially like architects but nevertheless, need to have a good understanding of a building for coordinating its service requirements. Virtual design studio based on similar collaborative notions using WIMPy VR with networked connections are being carried out successfully in several academic design institutions and design firms. In all these projects the simultaneity of response and feedback, in other words the real-time interactivity, has been more important than photorealism or immersion.

3. Conclusion

The inherent promise of VR technology in architecture lies in its use as *passive* and *exploratory* systems today. In the examples cited above, it has not only "enabled new possibilities" as in the Virtual Wheelchair project and the GreenSpace project but also "added value to existing possibilities" in architecture as in the virtual reconstruction projects. VR's use in architecture may not be as convincing as the real, due to the present software and hardware technology constraints, however it does enable us to perform tasks that were not possible before or facilitate us to do them more effectively. While much can be expected from future technology developments, such problems are not likely to disappear anytime soon.

Hence, from our research we found that even with its current limitations, VR has a potential impact on the way we conventionally think and design our built environment, pushing it beyond space and time constraints.

Appendix A:

1. Greenspace II, 1993–
http://www.hitl.washington.edu/projects/greenspace
The objective of the project GreenSpace II at HIT Lab at University of Washington was to apply the concept of distributed VR (distant participants present in shared virtual environment) to architectural design facilitating a remote discussion of the architectural space.



2. VirtualWheelchair Simulation, 1994
http://www.cgrg.ohio-state.edu/accad/re-3.html
The project at Advanced Center for Computing in Arts and Design of the Ohio State University proposes to examine the negotiation of spaces by the wheelchair users in a building before it is constructed, hence ensuring design of barrier free environments in order to assure handicapped accessibility to these spaces.



3. Matsushita's Kitchen system, 1994
[Bertol,1997. p. 125]
The project under the Virtual Space Decision Support System was an attempt to include the customer early in the design giving them a realistic estimation of the final kitchen product. The customer could choose from different designs, colors, or materials for the kitchen. This gave prominent publicity to VR and the company, despite mixed results with the product marketing.



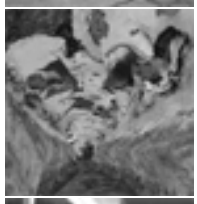
4. The Temenos Project, 1995
http://www.reconstructions.org/frames.html
The project is a digital reconstruction of the Athenian Acropolis in the 5th century B.C., using cutting-edge 3D computer modeling methods, done by the Museum of Reconstructions in collaboration with archaeologists at Princeton University and the Greek Ministry of Culture.



5. ALIVE Project, 1995
http://lcs.www.media.mit.edu/projects/alive/
The project, though of entertainment value, has significant implications on the collaboration and communication process in architectural design, practice and education. With the aid of virtual reality system, the project enables communication between people separated by physical distance on the same lines as 'teleimmersion'.



6. Lascaux Project, 1996
http://www.daap.uc.edu/CERHAS/benb/lascaux.htm
LASCAUX was the first PC-based heritage reconstruction project undertaken by Prof. Benjamin Britton of the College of Design Architecture Art and Planning at the University of Cincinnati. It is a virtual reconstruction of the famous ancient, painted, French cave at Dordogne, France.



7. Sitterson Hall Project, 1996
http://www.hitl.washington.edu/scivw/EVE/II.C/
VR was used to design better environments for disabled wheelchair occupants and other users of the Sitterson Hall building at Graphics and Visualization Centre, University of North Carolina, Chapel Hill.



8. Conceptual Design Space, 1996
http://www.cc.gatech.edu/gvu/virtual/DVE/DVE.html
The project undertook the creation of conceptual building designs through real-time, interactive virtual environments while being immersed in the virtual world at the Graphics, Visualization and Usability Center at Georgia Institute of Technology.



9. Augmented Reality for Construction, 1996–
http://www.cs.columbia.edu/graphics/projects/arc/arc.html
The project at Computer Graphics and User Interfaces Lab at Columbia University is a demonstration testbed for building construction, maintenance and renovation. Augmented reality construction system is designed to guide workers through the assembly of a spaceframe structure, to ensure that each member is properly placed and fastened.



10. Responsive Workbench, 1997
http://www-graphics.stanford.edu/projects/RWB
The workbench is being used at Stanford Computing Graphics Lab at Stanford University for site planning and design detailing. A virtual model derived from CAD plans for a new building is displayed on the workbench where existing design can be evaluated and new design aspects can be investigated.



11. Detroit Midfield Terminal Project, 1997-
http://www-vrl.umich.edu/NewMidfield/index.html
In cooperation with Northwest Airlines, the Virtual Reality Laboratory (VRL) at the College of Engineering at the University of Michigan developed a virtual model for the Detroit Midfield Terminal Project to assist in design evaluation and to support a complex decision making process.



12. Virtual Architecture Design Tool, 1999
http://www.vrac.iastate.edu/research/architecture/index.html
The project at Iowa State University's new Virtual Reality Applications Center (VRAC) examines the prototype of an immersive environment for interactive architectural design. This new approach allows architects to gradually build models in a virtual environment at various scales enabling direct design exploration as it is being developed.



References

Anders, P.: 1999, Envisioning Cyberspace : Designing 3D Electronic Spaces, The McGraw-Hill Companies Inc., New York.

Baker, P.: 2000, Visualization Spaces, Computer Graphics, November, Vol 34, No.3, 8-10.

Bar-Zeev and Jacobson.: 1994, Looking Back: A Retrospective Of Virtual-World Industry From The Year 2010, Computer Graphics World, May, 30-35.

Benedict, M. (ed.): 1991, Cyberspace: First Steps, The MIT Press, Cambridge, pp. 243.

Bertol, D.: 1997, Designing Digital Space, John Wiley and Sons Inc., New York.

Betsky, A.: 1997, Machine Dreams, Architecture, Vol. 86, No.6, 88-91.

Brooks : 1999, What's Real About Virtual Reality, IEEE Computer Graphics and Applications, Vol. 19, no. 6, Nov/Dec, 27.

Chesher, C.: 1994, Colonizing Virtual Reality: 1984-92, *Cultronix*—Volume 1, number 1. retrieved 14 September 2001 http://www.eserver.org/Cultronix/chesher/

Engeli, M.: 2001, Bits and Spaces: CAAD for Physical, Virtual and Hybrid Architecture at ETH Zurich, Birkhauser Architectural.

FakeSpace: 2000, Product Line, Domestic 48 states and Canada, Educational Price list. Sept.

Herzberg: 1968, Architects Open Computer Dialogue, New York Times, VIII, 1:7 April 21.

Hibbard, B.: 2000, Confessions of a visualization skeptic. Computer Graphics. August. Volume 34, No3, 11-13.

Jain, R.: 2001, Digital Experience, Communications of the ACM, March 2001, Vol. 44, No.3, pp. 40

Lanier, J.: 2001, Virtually There, Scientific American, April.

Lingard, B.: 1995, Human Interfacing Issues of Virtual Reality, retrieved 14 September 2001, <http://www.cs.wpi.edu/~matt/courses/cs563/talks/brian1.html>

Mitchell, William J.: 1995, City of Bits, MIT Press, Cambridge.

Negroponte, N.: 1970, The Architecture Machine: Toward a More Human Environment, MIT Press, pp. 35.

Negroponte, N.: 1995, Being Digital, Alfred A Knopf, New York, pp. 92.

Ohta, Y. and Tamura, H. (ed.): 1999, Mixed Reality, Mixing Real and Virtual Worlds, Ohmsha Ltd., Tokyo.

Pape, Dave.: 2001, CAVE Users guide, retrieved 14 September 2001 <www.evl.uic.CAVEGuide.html >

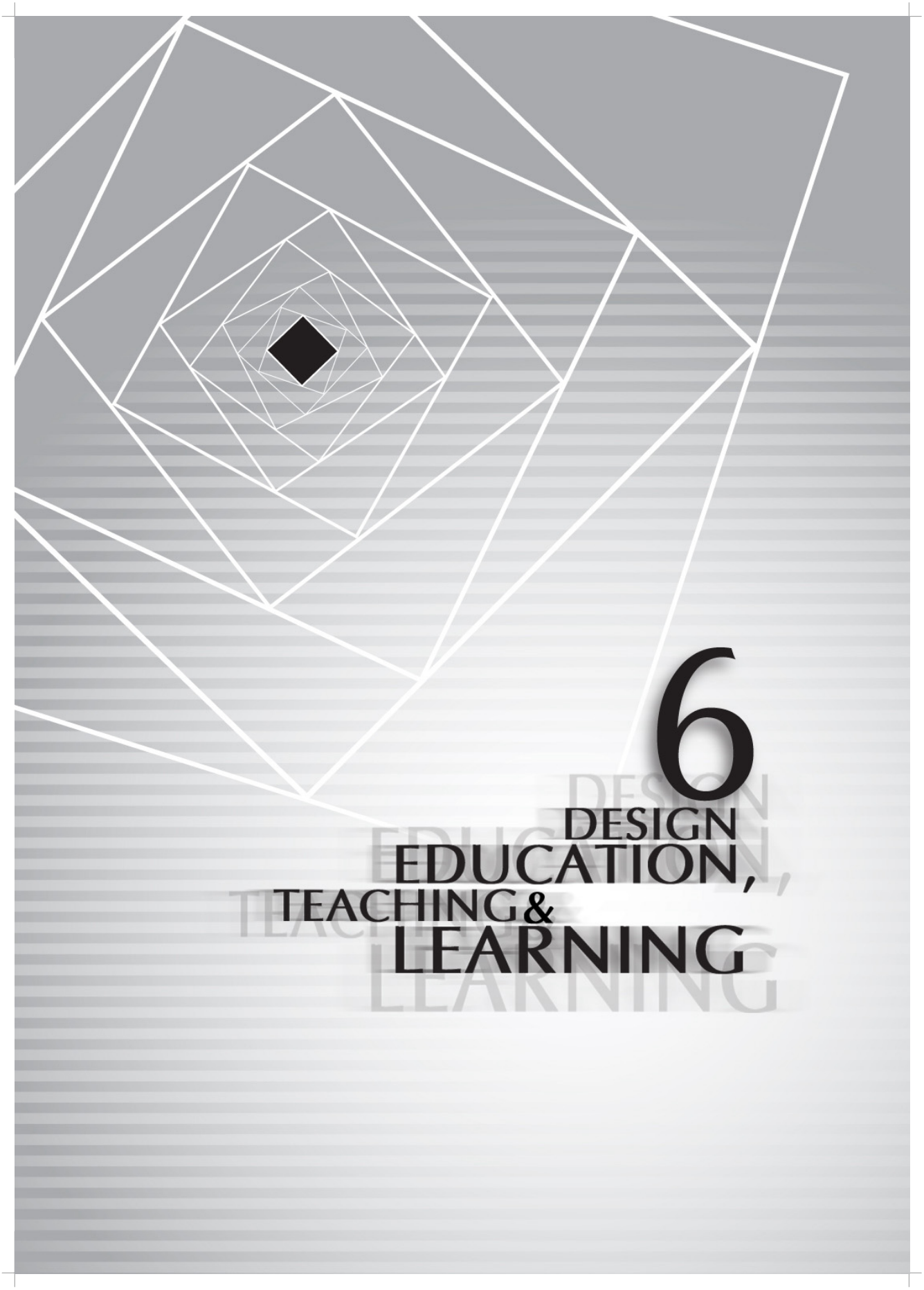
Pimentel K. and Texeira K.: 1995, Virtual Reality Through the New Looking Glass, 2nd edition, Intel/McGraw-Hill.

Schmidt, G.: 1993, Virtual Reality in Architecture, in Virtual Worlds and Multimedia, John Wiley and Sons Ltd., pp 85-97.

Sherman, B. and Phil J.: 1992, Glimpses of Heaven Visions of Hell. Virtual Reality and its implications. Hodder & Stoughton, London.

Steve, A., Blatner, D.: 1992, Silicon Mirage The art and science of virtual reality, Peachpit Press, Inc., Berkeley.

Van Dam, Forsberg, et all.: 2000, Immersive VR for Scientific Visualization: A Progress Report, IEEE Computer Graphics and Applications, Vol. 19, no. 6, Nov/Dec, 26-52.



6 DESIGN EDUCATION, TEACHING & LEARNING

6

Design Education, Teaching & Learning

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PRINCIPLES AND METHODS OF INTERFACE DESIGN

New Courseware to Design and Develop Electronic Products

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Abstract. Current problems in designing products or devices that carries content such as WAP phones, Digital Satellite TVs, PDAs and GPS Navigation system demands more than the traditional means of product or industrial design theories and techniques. Designers of such devices cannot rely only on physical appearance or technology alone. Interface Design, Bachelors in Multimedia course offered by the Faculty of Creative Multimedia, Multimedia University, is tailored to solve some of the above issues.

1. Interface Design: Introduction

One of the most common but not quite accurate description of Interface Design is the process of designing Graphical User Interfaces (GUI) for specific multimedia application. Here, the misconception is that interface designers only concentrate on the graphics or user interaction of an application including type of menu system and icons, docking / undocking, minimize / maximize of windows and components etc. Basically it is closer to graphic design for software engineering. This understanding is not exactly the Interface Design the Faculty of Creative Multimedia, Multimedia University is offering. For us, Interface Design is the medium between human and technology. Anything that help humans to access technology and make it part of our lives requires interface design.

2. Current Problems of Interface Design

To generate design via Interface Design process, traditional product/industrial design or software graphics design or a hybrid of both may not yield the desired

output. There are many instances where an electronic product or product that carries content is designed where heavy and comprehensive manuals and trainings are required before the product can be used. Limitations of technology or budget constraints for better parts and materials are often blamed. Worst still, many manufacturers of these devices separate the design of the physical aspects of the device from the GUI and technology. This is how our VCRs and satellite TV remotes becomes so unintuitive to use. There are many GUIs that doesn't follow the button layout or having important functions of a computer at the back end of a never-ending cascading menu. Increasingly becoming disjointed is the relationship between what we see, what we touch, how we operate and how we function at a particular time and work. The GPS system in a car can sometimes have as many as 40 to 50 buttons on the center console and we are expected to operate this system with one hand on the steering wheel and at least 90% concentration on the road. An Internet phone for the masses shouldn't have the complexity of a home computer to operate as it must cater for the rural folks and senior citizen who may or may not be computer literate. Buttons for a mobile phone should be aligned with the screen menu and be able to operate with minimum of keystrokes. No doubt that technology gives us so many functions and choices. This however cannot be the excuse not to design a good interface. As a bridge between human and technology, the interface design should help technology be used as if it's a second nature for us. The technology is designed for us to be closer in the first place, so why not make the bridge short, direct and easy to use.

3. Principles of Interface Design

To cater for the new age of technology, a new approach is needed for interface design. The approach culminates in principles of interface design that should define the design scope and link aspects of design such as technology, human and environment in a whole concept. The student's goal is to achieve a symbiosis between these aspects of design and provide credible, reliable and outstanding product. The principles of interface design are Positioning, Identity, Functionality and Technology.

3.1. POSITIONING

Positioning defines the scope of the design such as target market, complexity, type of technology used, physical and behavioural aspects etc. This principle is the best platform to compare the design with other similar products or services to clarify the goal of the design. It uses axes to define the extremes of the scope and positions the targeted area in which the design should reside. The position will be the goal of which the design should meet or surpass. An example of

positioning is the age of the target users of the design. For a kid's type electronic dictionary, the targeted clients would be set at 5 to 7 years old. The axis would stretch to cover similar devices such as electronic toys and e-book from age 1 to 15. The images of these devices are positioned within the axis as a reminder to the designers what the scope of design is. Axis can be quadrant based or more to cater for related positioning aspects. Pugh, S. (1990) says: "The user need, customer requirement, or voice of the customer is paramount to the succes or failure of the product". Another example of the use of positioning is to gauge the type of content and technology to be used or to mark an improvement over older or similar models that may be using slightly different or obsolete technology. Say, WAP and GPRS. WAP has the speed of the slowest modem at around 9 to 12 KHz whereas GPRS can give almost twice the speed of the fastest modem at 96 to 128 KHz. This means GPRS can carry content WAP can never deliver such as low bitrate video, medium resolution graphics and more complex applications. Positioning in this area should establish the new benchmark of the technology through the same concept of axis and place the design on its deserved position as reference during the design process.

3.2 IDENTITY

Identity defines the design theme and personality as a concept to be adhered to during the design process. The identity chosen should mould the design's ideation and development to generate a unique and integrated design. This is also a perfect platform to anchor the design specific to our culture, religion, race and/or way of life. Other than that, we can also create themes that reflect directly the reason for the design's being and the gist in which the technology is created. Besides that, identity gives a role for the design to breech the boring and generic concept most consumer products have and hopefully can give life to the design. One of the main goal of identity is to generate a theme for a design. Imagine a design of a pen for the blind. The pen only writes dots in Braille within a specific area of a pad and the pad would translate the Braille characters into words that can be pronounced via voice activation. In theory, the pen can look like any other pen and the pad can be just a simple rectangle. With identity, we can define a theme for the design such as "confident and smart", with a connotation that the theme reflects the user of the design. An image panel can then be created using the theme and anything and everything related to 'confidence' and 'smart' can be rasterized and put on an image panel with the strongest message as the biggest and more towards the center of the panel. Images that conjure 'confidence' and 'smart' can be a squirel (agility), a set of gears (precision), a compass (direction), phases of moon (time) and a book (learned). The design will then use abstract concept of the panel and enhance the design to achieve the theme "confident and smart".

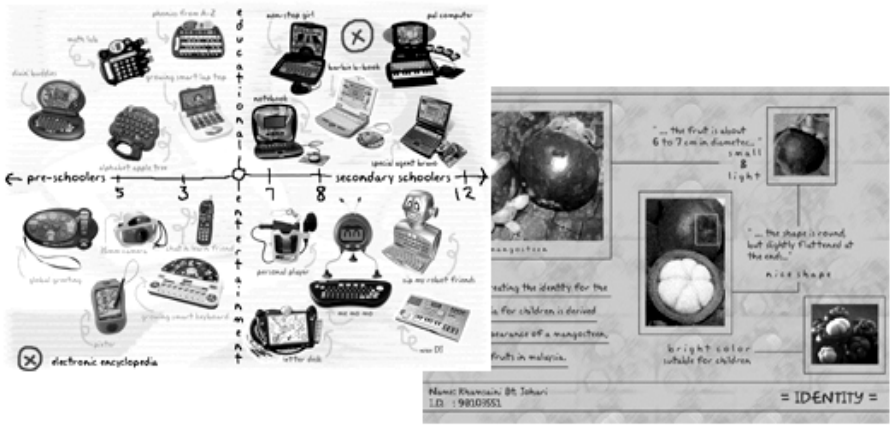


Figure 1*: Positioning and Identity panels*

Other themes for different types of design, for example, are “Nature”, “Futuristic”, “Lightness”, “Vibrant”, “Humble”, “Tough”, “Young”, “Cool” etc. We’ll then decide the best representation of identity for the theme we choose and the reason for choosing it. Abstraction of the identity can be in the form of outline, shadow, color, profile and extraction. One example from Apple computer, in 1982, Jerry Manock the designer who works with Steve Job creates a new identity for Apple’s computer product called The Snowwhite Project. Jobs loved the idea. Like the storybook characters, he wanted Apple’s products to exude a sense of charm and optimism, with a playful personality that would appeal to the child in everyone, and a sophisticated look that buyers would instantly recognize.

3.3 FUNCTIONALITY

Functionality defines the design’s features, usability and relevance. A navigation chart that lays the features and functions of the design is required. All interrelated functions must be linked and usually the most important and used functions are layered at the top of the chart and the least important and used at the bottom. Layers or segmentation should be marked or colored and text or image of each layer is of different size or thickness to reflect the importance. An example of functionality is a navigation chart of a menu structure of a satellite TV’s remote. At the very top is the power on button (most important – if the remote cannot turn the TV on, it is useless). The second level is the channel selection (should start with the last channel on or most frequent channel visited), The third level should be the adjustability of properties of the TV such as volume, color, contrast etc. The forth and subsequent level would be the connectivity to other services such as Internet, radio, pay per view etc. The bottom most level may include connection to other devices such as VCR, HiFi,

computer etc. Functionality chart should give the interface designers the ability to design based on function and should help to give more weight to the most important aspect of these functions. It should also create a link for different components of the design to work together as a whole and give intuition for the user of the design to be able to operate the finished product diligently and intelligently. The chart can also be used to integrate the physical appearance of the design and minimize unnecessary duplication of function.

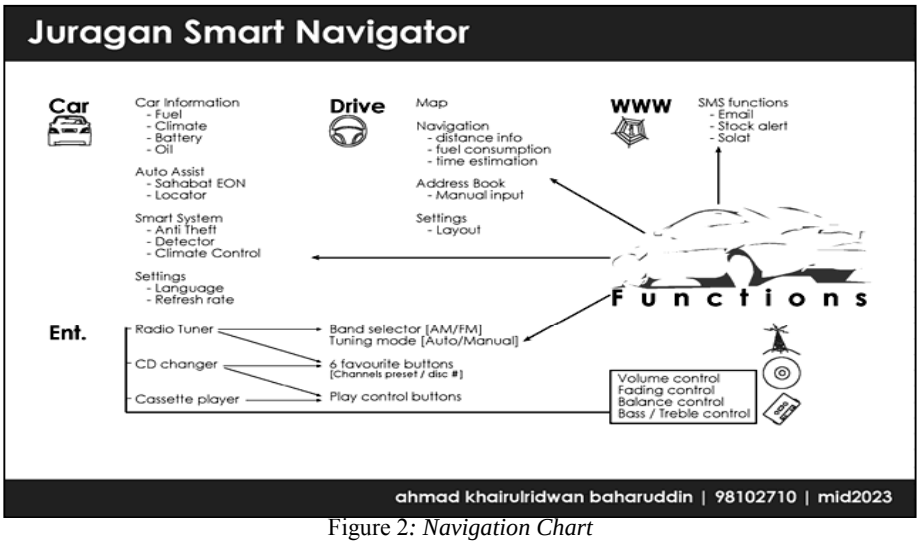


Figure 2*: Navigation Chart*

3.4 TECHNOLOGY

Technology is defined in interface design as a medium to accomplish specific task and application in a faster, more meaningful, highly informational and sometimes different ways. There are generations of technology that does what today's technology do but are limited in terms of speed and content. There are technologies that forever change the way we live and work. Sometimes we cannot run away from these technologies such as our TV and radio, our cars and our phones. It is an empowerment of content, information, transportation and communication that shape our lives. Karl T. Ulrich (1995) say: 'In developing technology-push products, the firm begins with a new proprietary technology and looks for an appropriate market in which to apply this technology (that is, the technology "pushes" development). To create a meaningful design panel for technology, we should be able to represent it as how it changes our lives or how we work. A storyboard is required for technology panel as it shows how we use the technology in our lives. For example, a navigation system for a car should have a storyboard on how we would use the system as we would in our car. The storyboard would show the navigation system main screen as displaying

information we usually need such as amount of fuel, distance can be covered by the fuel, date, time and the car's other vital information. The storyboard should also show how we operate the car and the navigation system together in a multitude of environment such as in traffic, while cruising, when turning and in different time of day and conditions. It should show the different displays required at each different environment and user requirement. Other than how we drive with the system, the storyboard may also show how the technology itself work such as connecting to a central server via receiving towers or satellite and downloading or uploading of information.

4. Methods of Interface Design

The design and development methods of interface design are formulated to give students exploratory ability within the Physical, Sensory and Applied interfaces. These interfaces deals with specific design issues and each can have a specific output that can be considered complete on its own. Design methodologies would start off with research using principles of interface design as guides. The output would be a design specification and a design brief. The second step is ideation. Ideation is in the form of generating design ideas in sketches, drawings, 3D modeling and mock-up models. The third step is conceptualization. Basically conceptualization ties design ideas together to form a meaningful interpretation of the ideation. The fourth step is development. Development executes the concept towards production of the design taking into consideration the user requirement, technological issues and cost to market. The fifth step is prototyping. Something concrete must come out from development be it a 3D model, Graphical User Interface or Diorama. The final sixth step is presentation. Students are required to present their prototype in a collective presentation that best reflect and represent the design to the world.

4.1 PHYSICAL INTERFACE

Design and development of physical interface requires understanding of all principles of interface design. Physical interface is used to generate design form in drawings, renderings, 3D or models. During ideation, traditional mediums may be used to develop ideas on the design form and its components such as sketches and renderings. Consideration should be given to shape, size, scale and properties of the form. During concept and development, 2D technical drawing, 3D modeling and rapid prototyping may be used. The final prototype can be interactive 3D models such as VRML or a real physical model at specific scale. Presentation of the design can be in the form of animation of the model and design boards. Physical interface uses product and industrial design techniques but the output shouldn't be compared directly to those disciplines. It should be

understood that physical interface designers are creating the bridge between human and technology. The quest for interface designers in creating physical form to satisfy their design requirements should be seen in that context. Aesthetics, ergonomics and functionality are the major concerns of physical interface. K. T. Ulrich (1995) says: 'Manufacturers used designers to style, or "gift wrap," after its technical features were determined. Companies would then market the product on the merits of its technology alone, although customers certainly evaluate a product using more holistic judgements, including ergonomics and style. But today, a product's core technology is generally not enough to ensure commercial success."

4.2 SENSORY INTERFACE

While physical interface develops the form, sensory interface concentrates on the content. Although interface designers are not true programmers and builders of the technology, they must understand the basic principles, properties and functions of the technology. They must challenge the programmers to maximize the potential of the technology through the medium and interaction they design. As sensory interface development is centered towards audio, visual, touch and interaction, the output during ideation would be the GUI, information layout and multimedia support. Concept would generate mock-up graphics at the required scale and display type for any given scenario. Development can then concentrate on building interactive representation of this concept together with the physical interface concept. The relationship of both has to established using the principles of interface design. Prototypes can then be created. Output of sensory interface would be a small program that simulates the applications of the design. An example of sensory interface design development is creating web content for Wireless Application Protocol (WAP) phones to help daily activities of a Muslim. A sensory interface design would generate ideation in the form of screen displays at different content of the WAP with physical interface based on popular WAP phones. Sensory interface designers should maximize the graphics limitations of a WAP content, for example to display prayer times and gives audio reminders of prayers. An application for prayer beads or *tasbih* can be created and the phone's up-down buttons can be used as counter. The beads with numbers would then scroll the screen and beeps when a certain number is reached. It is very important to understand the limitations of a particular technology before maximizing its sensory interface potential. Therefore, interface designers should check on their design principles to see the scope of design so that the design becomes relevant.

4.3 APPLIED INTERFACE

Applied interface shifts the weight of the design more towards the human aspect of interface design. Ergonomics of the design for targeted users is as important as the environment in which the design is being used. Ideation of applied interface can be study drawings between the design, the user and the environment. The study should encompass what happen when the design is idle and human is idle, when design is active and the user is idle, and when the design active and the user is active, in different possible environment. Concept would be creating application models for the various functions of the design. Development builds upon the relationship between applied, physical and sensory interfaces so they work together cohesively. Prototype can then output Diorama of the user with his/her environment while using the design. This diorama can be in 3D interactive model and/or physical models. Applied interface becomes relevant because the actual usage of the design in the environment is studied. The context in which the physical and sensory interfaces exist is now the applied interface.

5. Conclusion

Interface Design is not much different from other design disciplines. But, the interface design that Multimedia University is offering shows how important it is to create new generation that can cater for development of future products. Most product manufacturers do their own research to develop new technologies or try to apply some new technologies for their range of products. Interface Designer have their own role to fulfill this kind of design activity, starting from research which are product planning, product mapping and market segmentation that we believe no specific courses can cater for this kind of activity before. From there the task will go towards detail development until mass production.

References

Ulrich, K.T. and Eppinger, S.D 1995 “Product Design and Development”
Jerrard B., Newport R. and Trueman M., 1998, “Managing New Product Innovation”
Johnson, Mike, 1997, “Teleworking – In Brief”, Butterworth-Heinemann, Oxford.
Ryder, Judy, 1995, “Turning Your Great Idea into a Great Success”, Peterson, New Jersey.
IDSA “Design Secret” 2001 by Rockport.
Paul Kunkel 1997, Apple Design, The work of the Apple Industrial Design Group, Graphis

AN INQUIRY INTO COMPUTERS IN DESIGN:

When Cardboard Met Computer…

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Abstract. This paper reflects on the experiences of teaching undergraduate design studios for past 4 years and presents a systematic investigation conducted in a classroom setting to further understand the role of computer in conceptual stages of design. A case study project inquiring the implications of using two different forms of media, namely cardboard and computer, for design development during conceptual stages is presented. Twelve novice designers were challenged to learn and use computers in a five-week design project. A conceptual framework for understanding the discovery and usefulness of computer in their design process was developed and tested. An analysis of the outcome indicated that computers played a positive role in student innovation, improving possibilities for discovery. It further revealed that the employing cardboard was useful in turning the abstract discoveries made by the computers into productive and useful design solutions. It also supported the notion that the novice designer's use of photorealistic possibilities offered by computer visualization (rendering, animation) during conceptual stages of design had an effect of distraction rather than a design aid.

1. Introduction

Designers such as Gehry, Eisenman and Greg Lynn demonstrated innovative use of computers in their architecture. Many of our colleagues presented innovative student designs done on computers in recent ACADIA, ECAADE, and SIGRADI conferences. With the advent of increased power and reduced cost, computers have become standard tools in the designers' arsenal in recent years in both academia and the profession. However, most of the software programs available for designers (such as PhotoShop, AutoCAD, form·Z, 3D Studio, Maya etc.) are based on computer graphics principles and algorithms that are

devised for either documenting well-conceived ideas precisely or for special effects and animation [Dorsey & McMilan, 1998]. The internal representation and operational behaviour of available computer programs are not really geared for architectural problem solving [Yessios, 1986], but for assembling objects into scenes for creating imagery and animation effectively and efficiently. This encourages looking at the problems in parts than holistically [Turk, 2001]. Using such tools during conceptual stages of design in the place of conventional tools such as pencil and cardboard presents new challenges and problems in learning and teaching. This paper examines the computer as a design tool in an undergraduate studio-teaching context and the consequences presented by this condition to the student learning through a case study.

1.1 ROLE OF MEDIA IN CONCEPTUAL DESIGN

Goel [1995] demonstrated that cognitive processes associated with the preliminary design phase benefit from ill-structured, non-computational symbol systems such as pencil sketches. Dorsey & McMilan [1998] observe from a system designer's perspective that computer interfaces do not provide the fluidity and flexibility necessary for recording and exploring ideas during conceptual stages of design. Current computer graphics systems lack the ubiquity, accommodation for ambiguity and the elegance of pencil sketches on yellow trace to record the design process and compare multiple solutions simultaneously. Also they do not compare with the simplicity, tactility and flexibility offered by cardboard to work fluidly. For successful use of computers for design Clayton views both digital and tactile designs as necessary components of contemporary design teaching [Cuff, 2001: p202]. Further, the ability to change modes rapidly between traditional and digital domains is seen as a key by Dorsey & McMilan [1998].

It is widely accepted that novice designer's ability to use representational media for design is not innate; but is nurtured carefully through instruction along with practice, discussion, and contextualization [Lockhard, 2000; Welch et al, 2000]. However, in practice, most curricula do not integrate digital media well into the foundation level where students learn to apply representation for design. Instead, they are often taught as upper level elective courses with emphasis on specific software programs. There is little or no instruction of procedures or concepts about how to negotiate the interface between digital and traditional media [Bermudez & King, 1998]. This leaves a gap in students' ability to apply digital media for design. Consequently novice designers find it extremely difficult to adapt their design methods to computers and at the same time produce 'good' designs [Hanna & Barber, 2001]. Generally they resort to conventional media to deal with ideas in abstract to solve artistic and creative challenges, and only then seek computers to tighten up and present their designs after they evolve into a concrete stage. The project presented in this paper

examines this issue up close. It aims to provide the students with an experience in applying digital representation at conceptual stages so that they can see "what computers might do to and for them" [Simon, 1987].

2. Case Study

To provide a context, for the past 4 years, the author has been teaching a studio focused on using computers for design as an elective. The class typically consists of a total of twelve students (a mixture of Juniors, Seniors, and Graduate students) with a range of expertise with computer graphics media. All the undergraduate students in our program get a 7-week introductory exposure to digital media in their freshmen graphics media class. Some of them further their skills on their own through work experience and self-teaching. The majority of students lack experience in designing with computers, especially using 3D modeling. Self-assessment of each student's computer skill levels and attitudes towards their expectation of computers for design recorded on the first and the last days of the class that have helped continuously develop the course. The course consists of two successive projects. The first, normally four to five weeks in duration, focuses on "what we can do with computers and what computers might do to us" portion; the second, lasting for the rest of the semester (about 10 weeks) addresses "what we should do with computers and what computers might do for us". The project described in this paper provides an example of the effectiveness of the first project.

2.1 THE PROJECT

The design challenge was to design and build a small inspirational object to be placed on their desks (for the duration of the semester) based on a character that they liked as a child. This object was to be built from a single 18"X24" piece of cardboard, and it must be portable, monolithic, no larger than 6"X6"X6" and be able to sustain a fall of 4'. The expectation was that this project would lead to the subsequent major project: the design of a childcare center.

The Process

Stage 1: Design Manifesto; One half week;

Stage 2: Cardboard Interpretation; 1 week;

Stage 3: Computer Interpretation; 1 week;

At this stage, students were asked to interpret their design manifesto in digital realm using computer. Learning objective, to put it in Greg Lynn's [Cramer & Guiney, 2000] terms, was to take an inventory of what the machine wanted to do.

Stage 4: Cardboard Reinterpretation; 1 week;

The students were then asked to build a cardboard model of the solution

they had generated in computer, to distinguish what the computer wanted to do that cardboard could not.

Stage 5: Design documentation, presentation, & discussion; 1 week; See plate 3.

Analysis of the Outcome:

The student projects are summarized in plates 1 and 2. Each row (numbered 1-12), represents an individual students work and consists of four columns (labeled A-D). Column A shows the character student drew inspiration from, the subsequent columns B, C, D show an image from stage 2 (cardboard exploration), Stage 3 (computer interpretation), and Stage 4 (cardboard interpretation of digital solution) respectively. Column E records the influencing factors as noted by the student reflections using a conceptual framework provided to them by the instructor.

Summary:

Out of a total of twelve projects:

Three (1-3) had a high, five (4-8) had moderate, and four (9-12) had low level of discovery.

Eight accepted the transformations caused by digital as useful and desirable (1-8: corresponding to high and moderate levels of discovery) and four did not (9-12: corresponding to low level of discovery).

2.2 DISCUSSION

For brevity and to respect the page limits for the conference proceedings presentation of an analysis of individual projects is omitted. The conference presentation will include discussion on how computer differed from cardboard in materiality, generative and manipulation capabilities that affected student designs along with images. There were significant consequences to student learning because of the computer use. An important consequence is that the digital medium seduced the designer into exploring what it does best. The lure of facility for generating photorealistic imagery with relative ease had an effect of distraction rather than a design aid on some designers. Almost all students could not resist tinkering with rendering, even though the project did not ask for it and in fact required the project to be ultimately built with cardboard. Students explorative journey took a conspicuous detour from the moves normally permitted by cardboard, to novel image manipulating features of the computer medium. These explorations revolved around such attributes as transparency (for example: turning the cardboard translucent), reflectivity (making the cardboard shiny), surface patterns (applying decals of such material patterns as sand, wood, metal to change the looks of cardboard etc.). Although this resulted in the creation of spectacular looking imagery, most of these effects were erased

when the solutions were fabricated in cardboard eventually. This is consistent with Balfour's [2001: p268] cautions that computers can fool us into believing that we are empowered when, in fact, we are seduced.

Limitations of the study

This study, although systematic, is not scientific and has a several limitations. The inexperienced student sample used represents one limitation to the generalisability of our results to practicing designers. Skill of the designer (dexterity with visualization medium), nature of the project, time allowed for design, and the direction provided in the critiques could significantly affect the outcome in a design context. We did not adequately address these issues in this analyzing this project outcome.

3. Concluding Remarks

From an educational point of view, do computers improve or inhibit architectural design process? What are the consequences to student's learning and studio culture? The general consensus among the students is not that one was better than the other, but using them in concert enriched the design process. Employing cardboard to concoct the abstract discoveries helped students to make their design more useful and meaningful by bringing the physical issues to the forefront. This is consistent with Parson's [1994: p175] observations virtual environments have the potential to contribute as much to the design process as traditional design processes if used in conjunction with them. This leadoff project had a positive effect on the subsequent major project by improving the student restraint of irrational possibilities offered by the digital imagery during design development. In summary, this paper concludes that incorporating computers in architecture studio curricula calls for changes in course content and teaching practices to develop sensibilities in students about technologies (when/how to use and when/how not to use), and the learning environments to accommodate the interactions of the new media in a way to enrich but not to displace the traditional. Teacher's familiarity with the scope and limitations of software, hardware available at hand seem very important in effectively guiding the students through the process. When computer falls short, we need to know to use our knowledge of design and teaching to guide computer use.

Acknowledgements

I sincerely thank my colleagues Prof. Ann Cline and Prof. Tom Dutton for reading a preliminary draft of this paper and providing valuable comments. I also thank my students

whose work is presented in this paper for their dedication and enthusiasm. Last but not the least, I thank Ms. Tina Sarawgi for being a wonderful graduate assistant for this class.

References

Balfour, A (2001). "Architecture and Electronic Media", Journal of Architectural Education, Vol 54, No 4, May 2000, ACSA Inc, Washington DC, Pp 268-271.

Bermudez J, King K (1998). "Media Interaction and Design Process: Establishing a Knowledge Base", Eds Seebohm T, Van Wyk S, Digital Design Studios: Do Computers Make a Difference? (Association for Computer-Aided Design in Architecture Conference Proceedings) Pp. 6-25.

Cramer N and Guiney A (2000). "The computer school: in only six years, Columbia University's grand experiment in digital design has launched a movement", Architecture Sept 2000, Vol 89, No 9. Pp.94-107

Cuff D (2001). "Digital Pedagogy: An Essay". Architectural Record. September 2001. Pp 200-6.

Dorsey J, and McMillan L (1998). "Computer Graphics and Architecture: State of the Art and Outlook for the Future," Computer Graphics, Vol 32, No 1, Feb 1998. Pp. 45-48.

Goel V (1995). Sketches of Thought. MIT Press.

Hanna R and Barber T (2001). "An Inquiry into Computers in Design: Attitudes Before–Attitudes After", Design Studies, Vol 22, No, Elsevier Science Ltd, Great Britain. Pp 255–281.

Lockard, W, (2000). "Where We Have Been. The Recent History of Design Communication". Design Communicators Association 2000 conference Keynote speech. http://scholar.lib.vt.edu/ejournals/JDC/Spring-2000/kirby/kirby.html accessed 01/15/2002.

Parsons P (1994). "Craft and Geometry in Architecture: An Experimental Design Studio Using the Computer", Eds. Anton Harfmann and Mike Fraser, Reconnecting (Proceedings of Association for Computer Aided Design in Architecture Conference) Pp 171-6.

Simon H, (1987). "The Steam Engine and the Computer: What makes Technology Revolutionary?", EDUCOM Bulletin 22, no. 1, Spring 1987. Pp 2–5.

Turk, Z (2001). "The Reasons for the Reality Gap in CAAD", Ed Penttila H, Architectural Information Management (Proceedings of 19th Conference on Education in Computer Aided Architectural Design in Europe), Helsinki, Finland. Pp 156-60.

Welch M, Barlex D, & Lim H (2000). "Sketching: Friend or Foe to the Novice Designer?". International Journal of Technology and Design Education.

Yessios C (1986). "What has yet to be CAD". ACADIA Workshop '86 Proceedings. Houston. Pp. 29-36

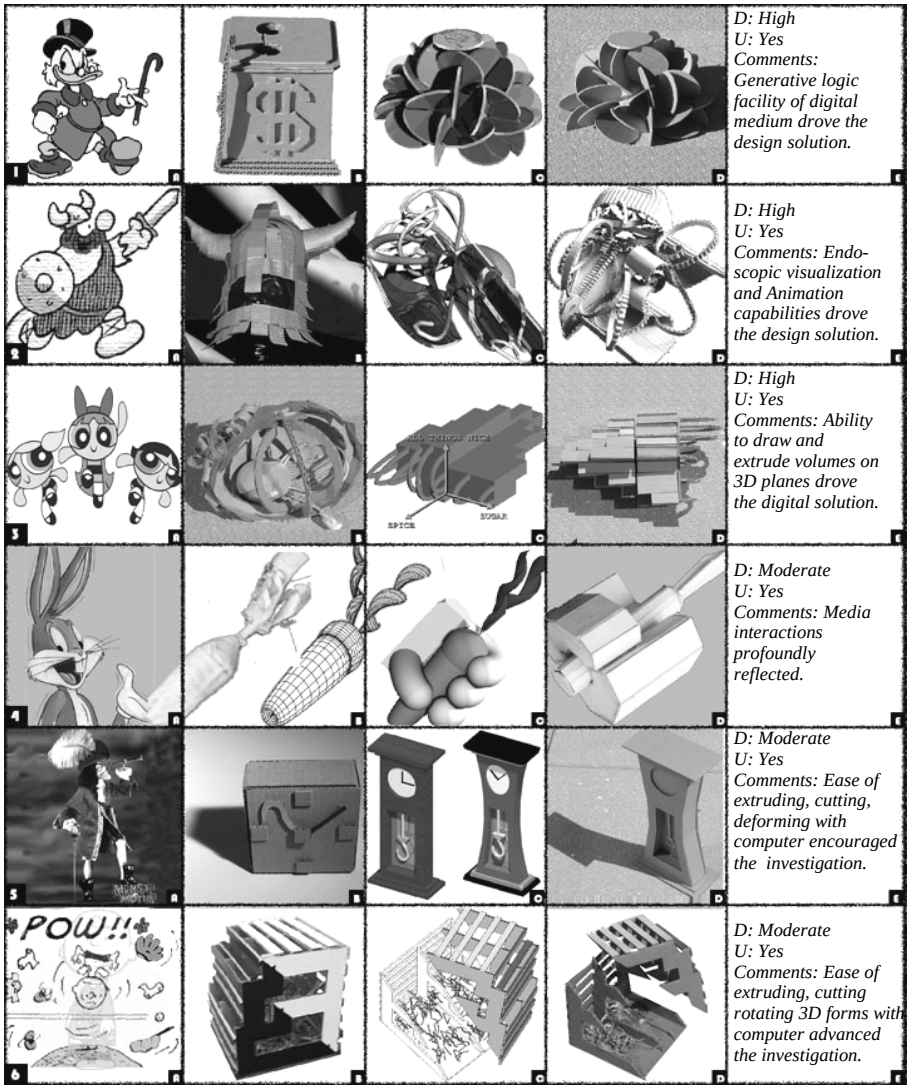


Plate 1
Analysis of student work from ARC 301, Fall 2000 at Miami University

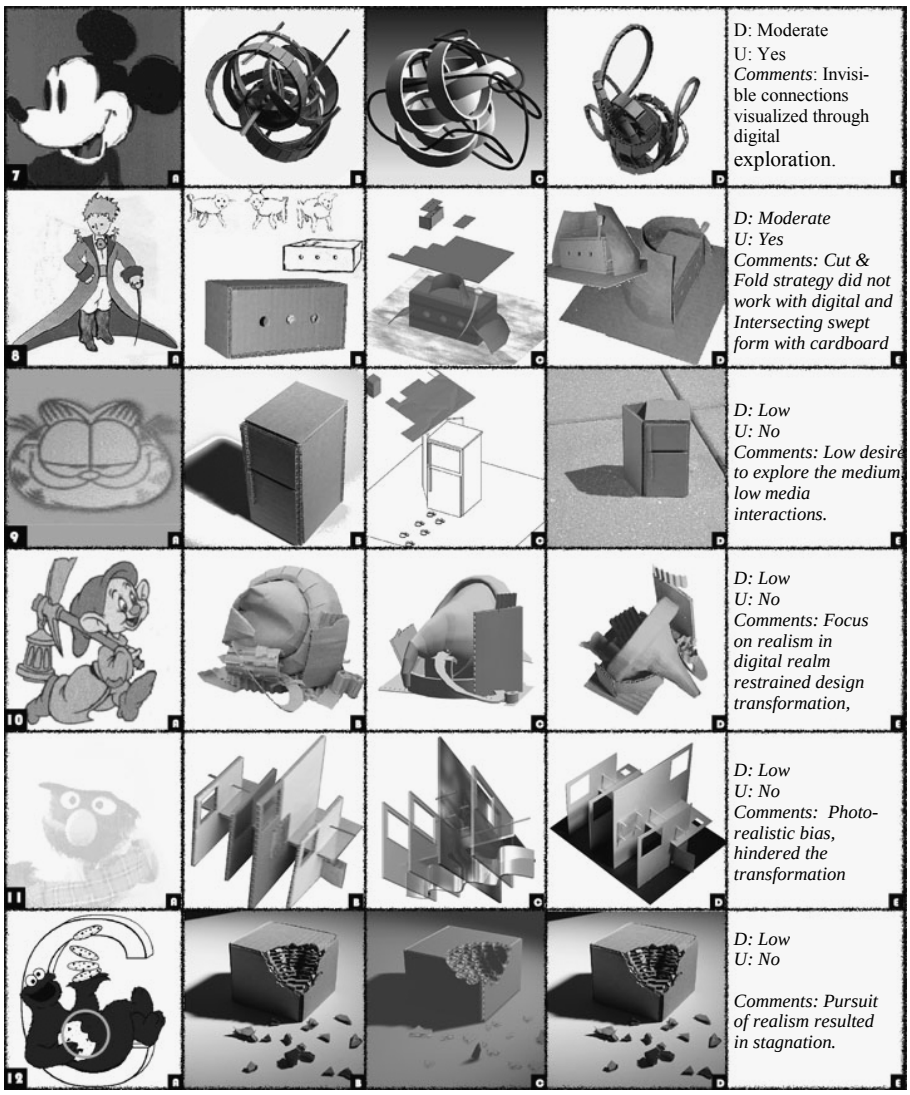


Plate 2
Analysis of student work from ARC 301, Fall 2000 at Miami University(continued)



Plate 3. Example of 24”X36” student poster (Matt Nudelman, Fall 2000) comparing cardboard and computer generated design solutions along with critical self-reflections on the effect of process on the outcome.

DISCOVERING CONSTRUCTION THROUGH ARCHITECTURE

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Abstract. This paper discusses a digitally integrated educational programme wherein students discover construction through architecture' from innovative and technologically diverse student projects using digital and physical media within a role-play environment. Student output is examined to determine engagement in a programme informed by 'reflective making'. This redefinition of content is centred on priming graduates with the abilities and skills to lead the construction industry of the future.

1. Why Redefine Content for Construction Education?

According to a recent Australian government report, the construction industry in the 21st century is characterised by 'evolving industry structures and new technologies driving change in the workplace' (DIST, 1998) Public and private sector clients are more often seeking IT integrated packaged construction services, a significant move away from the traditional, adversarial nature of the industry. The overall goal is 'an innovative, leading edge, and environmentally sustainable industry, well integrated into the Asia/Pacific region'. (DIST, 1998)

Key ways of achieving these aims include;

> 'Wide uptake of information technology through all levels of the industry as an enabler of greater efficiency and competitiveness' and 'development of "seamless" and "virtual" organisations' (DIST, 1998)

The construction industry is currently in a transition phase, with uptake of these technologies limited primarily to larger organisations. This university sees the immersion of students into information technology and digital media as a means of preparing graduates of for the industry of the 21st Century. (Deakin, 2000) It is contended that early years tertiary education is an ideal stage to prime students for the transition of the construction industry to IT-enhanced modes of operation.

This paper reports on the design, delivery and assessment of a digitally integrated educational programme for students of Construction Management and Architecture undertaken at Deakin University's School of Architecture and Building in semester 2, 2001. This programme redefined content to help equip graduates with the skills to innovate and lead the future construction industry.

2. Programme Inspiration and Aims

The learning programme under discussion was inspired by the CUTSD (Committee for University Teaching and Staff Development) 'Reflective Making' project, an inter-institutional project involving Deakin University, Adelaide University and Victoria University of Wellington. The broad aims of the project were the creation of 'a new learning culture which expects, encourages and rewards innovative and wise use of computers in student designing' through a rich culture of 'reflective making'. (Radford et.al. 2001) Learning material was developed with the assistance of later year students, (Woodbury 2001) embodying 'reflection-in-action', (Schon, 1987) design making and innovative use of computing, together known as 'Reflective making'. The CUTSD project diversified to include 'Technology Projects 2', a core unit in the Bachelor of Construction Management at Deakin University. The content of the unit was re-defined to capitalise on earlier student initiation in 'reflective making' in their first semester construction unit. (Ham 2001)

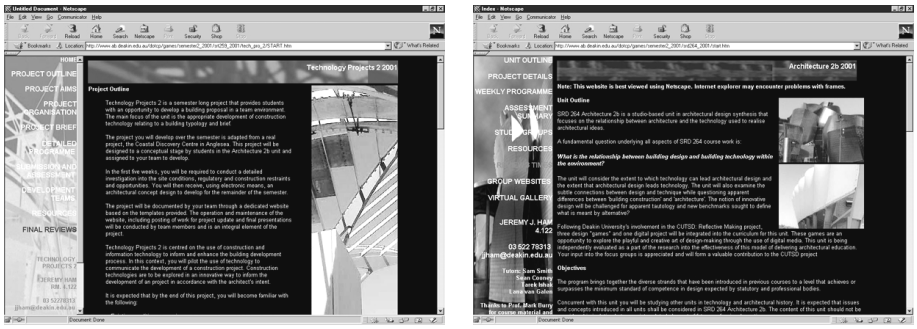


Figure1. Project delivery webpage; Technology Projects 2 (left) and Architecture 2b (right) from http://www.ab.deakin.edu.au/online

The programme under discussion has five defining characteristics:

1. Electronic delivery, submission and assessment of all units involved in the project (refer Figure 1);
2. The immersion of students into a virtual and physical role-playing environment involving *development teams, clients, architects* and *consultants*

as players;
3. 'Learning construction through architecture', through the collaborative development technologically diverse student architectural projects;
4. The use of the Internet and the electronic network as the primary form of communication of design and construction information.
5. The grounding of student's immersion into virtual environments within the context of physical construction.

3. Programme Design

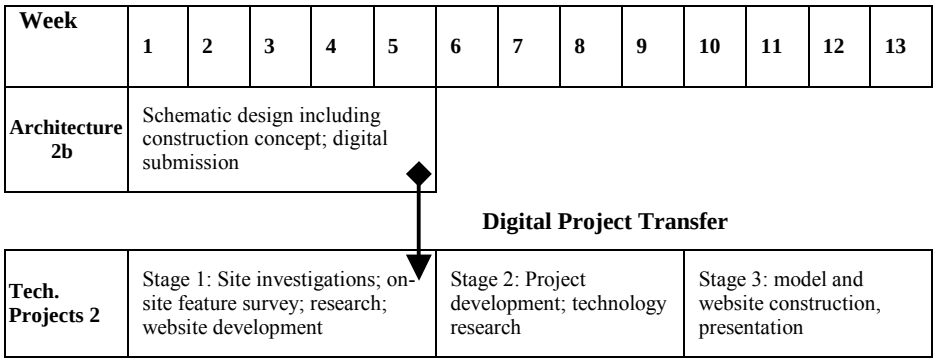


Figure 2. Integrated Project Timetable

3.1 ARCHITECTURE 2B

The second year architecture project, 'Discovering Architecture', was delivered over the Internet in the first 5 weeks of semester 2, 2001, (refer figure 2) accompanied by a series of lectures, workshops and industry guests. Within the design, architecture students were required to address design conception, social and environmental issues, brief development and form making. The presentation of the project was limited to digital media, based on a PowerPoint template downloaded from the unit website. Templating of the project ensured consistency of design information. Student architects were instructed think carefully about ways to communicate their design intent on their presentation. Elements of the template included site and floor plans, building form and construction concept. (Refer Figure 3) Reviews were held directly from the electronic network in design studios.

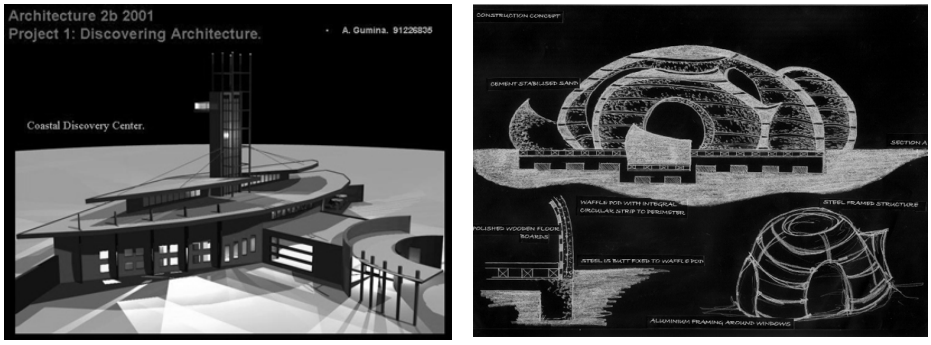


Figure 3. Diversity of Discovering Architecture Submissions: CAD model (left) and freehand sketches scanned into digital template (right)

3.2 TECHNOLOGY PROJECTS 2

The Technology Projects 2 unit was re-defined to reinforce understandings of construction theory within a practicum of the construction industry. The use of a digital submission system through the school-based server and electronic network enabled Architecture 2b projects to be assessed digitally and a selection of eight projects to be transferred to network folders maintained by eight teams of six Construction Management students.

These students then assumed the role of developers charged with the task of researching construction issues and delivering a constructed representation of the architect's design concept. The developer teams were provided with a basic web template to be used as the primary form of communication of the developed concept. Regular project update meetings consisted of a team web-based presentation to staff at key stages of the project. Staff visited websites weekly for formative assessment of the project.

The final review consisted of a team presentation including the website, model and developmental work attended by staff and the student architect author of the project whose role it is to judge of the delivery of design intent (refer figure 6). Essential construction management skills such as team building and teamwork, research, site surveying and analysis, and connectivity with the industry were counterpointed by the use of information technology to enhance the development process. This virtual component was balanced by the use of physical models to represent the finished building. This dialogue between the real and the virtual is seen as a key component of the programme that enables students to explore the real world of construction using the tools of their generation.

4. Evaluation of Student Responses

4.1 ARCHITECTURE 2B: 'DISCOVERING ARCHITECTURE'

Examination of student responses to the project found that they had undertaken considerable advancement in their mastery of digital media. Earlier initiations into the use of MicroStation, Rhino3D, PowerPoint and PhotoShop led to a high level of sophistication in the presentations relative to paper-based media. (Refer Figure 4) Some students in the cohort, however, encountered the usual problems of appropriate construction systems selection, brief development and the formulation of 3D concepts.

The theme of 'discovering architecture' gave students licence to explore new ideas, facilitated by the Internet as a source of inspiration. This led to an interesting array of design concepts selected for development, including stylised phytoplankton, a deconstructed shipwreck, a subterranean labyrinth and a design inspired by the chiaroscuro of a forest canopy.

Diverse construction technologies represented by the selected projects included, laminated portal frames, complex curved panel construction, straw-bale, timber and steel framed construction, tilt-panel and in-situ concrete and teratecture. This provided fertile material for the construction management students to 'discover construction through architecture'. The project brief required not elevations but a 3 dimensional visualisation of the building form. This led to the wide usage of 3D CAD models as a faster alternative to traditional hand-drawn perspectives and axonomentric drawings. The most successful outcomes however were presentations that utilised a composite of media including scanned images of hand-rendered drawings and models that captured the essence of the design and the individual style of the author. Experience shows that CAD-based representation, in the hands of early years students, is rarely used in a way that positively informs the essence of the design concept.

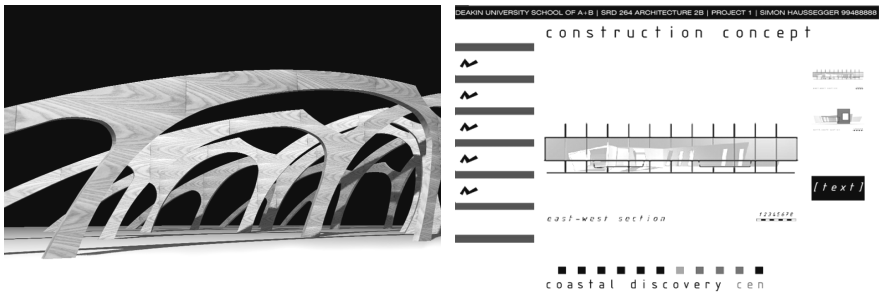


Figure 4. CAD model of Construction Concepts for a scheme selected for development (left.) Flash utilised in presentation. (right)

4.2. TECHNOLOGY PROJECTS 2

Student engagement was very high, with teams taking ownership of the project, organising themselves, and meeting deadlines. A student feedback survey included comments that the project helped with 'teamwork-problem solving', 'the importance of group consultation' and 'exploring alternatives'. Several students felt that 'its been an enjoyable unit'. Students generally felt that they had advanced both their digital skills and understanding of the workings of the industry.

4.2.1. Construction Models

For second-year students, the level of attention to construction issues was generally high, considering the difficulty of some of the schemes. Physical models were accompanied in some instances by CAD models, drawings and 1:1 detail models. Images of models were successfully integrated into all team webpages to represent the finished scheme. (Refer figure 6)

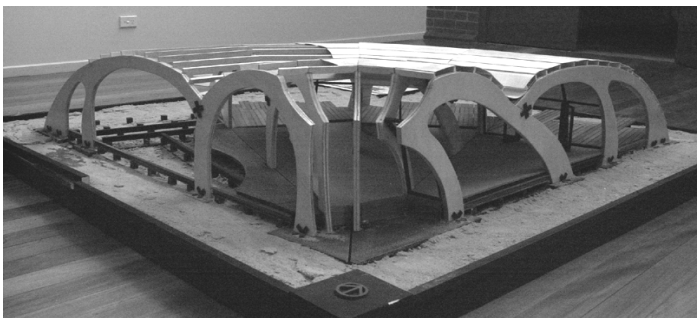


Figure 5. Final construction model for the architect's scheme in Figure 4

4.2.2. Web Pages

Students very quickly engaged with the use of Dreamweaver, Flash PhotoShop and MicroStation to communicate the development of their projects. A template was provided as a scaffold, however all eventually teams developed their own web page identity. (Refer figure 6) After an initial learning curve, students quickly engaged with the media and extended their websites to gain a competitive advantage.

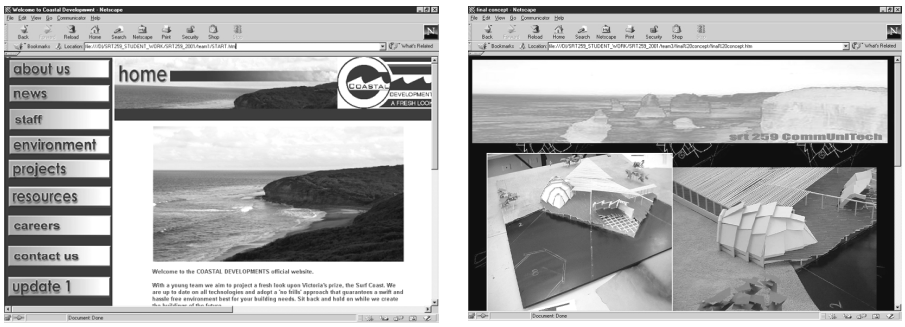


Figure 6. Development team websites. Home page (left) and finished model images (right)

4.2.3. Presentations

At Project Update Meetings, student teams quickly adapted to the use of websites to accompany verbal presentations. Some teams demonstrated near professional presentations with delegated speakers, coordinated uniforms, business cards and follow up letters. For others, this was a mask to the deflect attention away from poorly developed schemes. The original design architect was present in most reviews to pass judgement on the way in which the developers delivered their design intent. (Refer figure 6) In this process, some teams were subject to intense scrutiny about the way they developed design concepts. Some teams chose to extend and modify concepts, because of constructabilty or other issues, whilst others followed design intent closely. Presence of architects in reviews also encouraged peer learning and reflection on their developed designs. The final presentation was the culmination of a semester's work; bringing together the website, physical and CAD models, 1:1 details, CAD drawings, reports and verbal presentations. Several teams achieved a balance between the real and the virtual; using appropriate digital and physical means to communicate their development of the scheme. It is the confluence of these modes of communication wherein the strength of the project lies.



Figure 6. Final Presentations: Website projected from network points (left); design 'architect' passing judgement on development model in final review (right)

5. Conclusion

The educational programme under discussion is an exemplar of a way in which IT may be used to facilitate integration between units in a practicum based on role-play. 'Discovering Construction through Architecture' is a means by which can learn about construction from innovative and technologically diverse projects using a balance of digital and physical tools to enhance the development process. Significant peer learning opportunities are provided through collaborative work, peer review and online websites.

The high level of student engagement with reflective making provides evidence of a successful redefinition of content centred on priming graduates with the abilities and skills to lead the construction industry of the future.

6. Future Directions

A Memorandum of Understanding with Bentley Systems will enable the use of Project Wise to facilitate secure web-based submission of 2002 Architecture 2b project as well as providing a platform for integrated project development.

Acknowledgment

The author would like to thank the CUTSD team, student 'architects' and 'developers' involved in the project, tutor Mr. Rodney Ball for assistance in the delivery of the unit. The author would also like to thank Bentley Systems for their support of the online projects initiative at Deakin University.

References

Department of Industry, Science and Tourism; 1998, Building for Growth: Foundations for Australia's Future, Canberra. (http://www.isr.gov.au/growth/html/building.html)

Deakin University; 2001 'The Deakin Advantage'. Deakin University Press 2001

Ham, J.J.; 2001 The reflective making of 'games' for construction education, Playful Learning Design Forum (http://www.arch.adelaide.edu.au/games/forum/index.html)

Radford, A.D., Woodbury, R.F., Burry, M, Shannon, S, 1999. Committee for University Teaching and Staff Development application "Reflective Making: Higher Order Learning in Early Tertiary Architectural Education".

Schon , D, 1987 'Educating the reflective practitioner '/San Francisco : Jossey-Bass,

Woodbury, R, Wyeld, T, Shannon, S, Roberts, I, Radford, A, Burry, M, Skates, H, Ham, J, and Datta; S. 2001."The Summer Games " Proceedings of ECAADE 2001 H. Penttila editor

DESIGNING WITH COMPUTERS IN A PAPERLESS DESIGN COMPUTING STUDIO

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Abstract. The advancements in digital design and communications are reshaping the economics of architecture and design practices. Designing with computers is based on establishing a fruitful dialogue between the designer and the tool. The "digital imperative" to switch from analogue to digital mode have already begun to manifest itself at the schools of design and architecture in the form of the paperless Design Computing Studio (DCS). This paper describes and reflects on the designing and teaching approach implemented in a paperless DCS within the domain of architectural design. The paper presents the implementation of this approach, on the first year students of the new degree of Design Computing at the University of Sydney and analyses the students' design learning experience in the DCS.

1. Introduction

The "digital imperative" to switch from analogue to digital mode have already begun to manifest itself at the schools of design and architecture in the form of the paperless Design Computing Studio (DCS). Design and architecture students will routinely use the best of new technologies within information-rich and fully networked, multimedia environment (Muir and O'Neill, 1994). The advances in design computing and digital media in the last decade have been phenomenal and what the next decade will bring can only be imagined.

However the advancements in digital design and communications are already reshaping the economics of architecture and design practices, many of the design and architecture schools are still using manual techniques similar to those of the beginning of the last century. Our approach for

designing and teaching in the paperless DCS at the Faculty of Architecture, University of Sydney as a new design medium is inspired by Schmitt's (1997) view of the computer as a design medium that is more than a tool and it is an interactive counterpart through its capabilities and what it offers. Our approach to a paperless DCS is also motivated by Resnick's (1996) view to new paradigms of computing as new paradigms for thinking and Madrazo's (1999) assumption that designing with computers is based on establishing a fruitful dialogue between the designer and the tool.

The comprehensiveness of a successful paperless DCS allows for design ideas to be created, sketched, developed, drafted, rendered, and animated in real-time. The digital design is then printed, presented on-screen or projected, sent around the world over the Internet, and even fabricated by a numerically controlled rapid-prototyping machine, without ever existing on paper.

The thrust of this paper is not about the software, hardware, and networking configurations and the potential of these configurations to accommodate emerging digital technologies in a paperless DCS. The focus here is on addressing designing and teaching strategies that are most suitable in a paperless Design Computing Studio (DCS) environment. Furthermore, reflecting on the effect of the application of these strategies within this new environment on the design ideas and artefacts created by students while designing with computers without the use of a drawing board. This paper presents the implementation of this approach, on the first year students of the new degree of Design Computing at the University of Sydney and analyses the students' design learning experience in the DCS.

2. Designing with Computers: Why Paperless?

The infusion of digital media into the practice of design and architecture is changing how the design process is carried out as well as what is designed, i.e. artefacts, and the culture of design education. There is a transition from a completely analogue system of representation to one of complete computer immersion or the "paperless studio". Design and architecture schools have already begun to struggle with the physical issues of either integration of new media or going completely digital (infrastructure and economics). However, the pedagogical integration should be of a greater concern. New media and its forms of representation are challenging traditional skills of communication and representation. Changes in practice as well as design education should look to new media with the opportunity for further exploration of design ideas, creation of new forms and new design vocabularies. The creation of new forms comes with a responsibility of seeking new forms of representation (Norman, 2001).

It may be asked why is it necessary to provide digital immersion environment in which traditional models for design exploration such as physical models and manual drawings would be excluded? An attempt to answer this question is with the question, why does it seem satisfactory to exclude digital media when exploring with traditional methods. The validity of a paperless design studio lies in the notion that digital media can change the process of design, the forms of design and how design ideas are communicated. A comparison could be made between a paperless DCS to a studio that has been instructed that the only medium for exploration will be casting. A casting studio would force changes in ones process, forms and experience (Norman, 2001). To draw a parallel to the paperless design studio, one needs to become aware of the unique abilities of what digital media offers and how it can be used to explore the design process. Digital models and web-based project sites are becoming normal practice within the real world of building construction. As the world becomes a more global society, the ability and means to transfer, communicate and collaborate design ideas in more efficient ways and timely manner is ever increasing.

2.1 DESIGN TOOLS IN A PAPERLESS DCS

Design tools in a paperless DCS should be primarily employed at the conceptual stage of designing and at an early level of design education to provide the opportunity for the students to comprehend the use of computers as design medium instead of a tool solely for drafting. As design tools are incorporated into the design process the student's ability to test and investigate design ideas becomes more thoroughly.

Using design tools that are object and time-based at the conceptual stage of designing is quite important. Utilising objects in a design tool is simple to conceive and in having the ability to simulate reality. And time-based animation allows one to approach, test and investigate a simulated reality. Greg Lynn (1999) describes animation as "evolution of a form and its shaping forces". The use of time-based media in the paperless DCS allows understanding objects in space and its relationships and influences over other objects. The indiscriminate application of computer design tools at the conceptual stage might allow the student (designer) to be removed from the design process and the software to be in control of the design outcome, however designers must be in control of the design tool (software) and design outcome. The ability to utilise the computer as a design tool comes with a responsibility of understanding its' limits and its' role as a tool for inquiry.

2.2 PEDAGOGICAL CONCERNS

Moving to a paperless DCS is more concerned with the pedagogical issues of integration and how to infuse the computers into the design process. This is a larger educational issue of concern compared to how to afford and place computers into a design studio that is financial or organisational dilemma on the part of institution or the student. The success of a paperless DCS relies on the ability of its students and faculty members to implement these new digital tools and to change the culture of the design studio environment. If students are not adequately taught the digital skills of concern in advance, the digital media will not become part of a process of design and will be degraded to instructional labs for software training. To avoid weakening the pedagogical endeavour in a paperless DCS, the students need to learn the related digital media tools and use the computers as a design tool for inquiry and exploration (Norman, 2001).

3. Design with Computers in The Paperless DCS

Our first year design computing students have been given a brief to design a café on a vacant land next to the Faculty of Architecture's Tin Shed Gallery and were asked to design this café using ArchiCAD as a platform. ArchiCAD is very effective software that can be utilised as a design tool at the early stages of the design process and it satisfies the criteria outlined in section 2.2. Other digital media tools such as Adobe Photoshop, Microsoft Powerpoint, Macromedia Flash and Dreamweaver were used in the paperless DCS as image processing and presentation tools. The typography and surroundings of this land were modelled by the students in ArchiCAD. The climatic changes and effects on the site from surroundings were calculated and presented using ArchiCAD at specific hours of the fours seasons as shown in Figure 1, e.g. 3pm. This had a primary effect on where the proposed building might be located on site to avoid the overshadowed areas. The students have produced a QTVR animation showing the analysis of shadow studies. This simulation of reality was of a great importance to the students and facilitated their understanding of the climatic effects on design.

A major teaching and designing strategy that has been elaborated in the paperless DCS is that the limitations of ArchiCAD as the platform should not be considered as constraints in creating design ideas but rather utilise its capabilities as primitives in developing various design ideas. Instead of viewing the platform as a shell to generate typical and routine designs, it is rather to facilitate the features of this platform as a starting point to explore design ideas. This approach had a great impact on how the students interpreted the brief depending on where and how they started to explore

their designs and which features of the platform were selected as design primitives to create and compose their design ideas. Some examples of students' diverse design ideas are shown in Figure 2. Students have also found that the experience of designing with computers within this approach has opened up an enormous amount of new design ideas and imaginations for them that may have not crossed their minds if they were designing on paper or constructing physical models. Not only are their ideas become richer and innovative, but also were able to test the behaviour of their designs, such as climatic changes to achieve thermal comfort, colour and texture scheme to achieve aesthetics and harmony with the surrounding environment, etc.

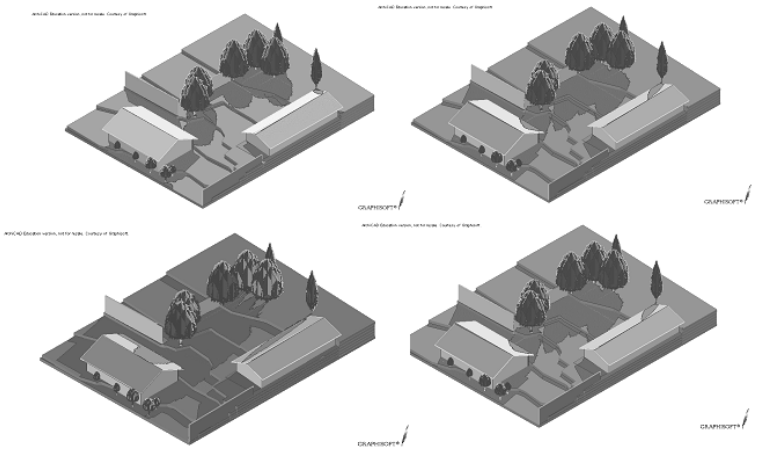


Figure 1. Land topography and shadow analysis of the proposed site to design a café.

4. Reflection on Designing and Teaching in the Paperless DCS

4.1 DESIGN PROCESS IN THE PAPERLESS DCS

In the conventional design studio the design process have been stressed through the use of sketching, physical modelling and orthographic drawings. A unique characteristic of the conventional design studio is that sketching, tracing and recording ideas are left visible. This provides richness to the exploration through revisiting and revising previous ideas. The ability to see where a design idea is at present and where it came from seems to be a benefit of working in a physical or tangible medium. All of this and more can be offered using digital media in the paperless DCS (Norman, 2001).

The history of a project and process of design must be evident in the educational techniques employed in the paperless DCS. Editing a digital file might cause the history or part of the design process to be lost. This was simply resolved by using the design tool to benefit the design process in the paperless DCS. Whenever a design idea was revised a new file was saved providing a record of the past. This strategy was not applied by our students at every change in the design process but rather at times of conceptual changes. Another alternative to document the design process is with taking frequent captures and snapshots of the computer's screen state, well prior to final presentation. This allowed the students to see the evolution of their designs from various concepts to design developments. The documentation of the design process in the form of a digital sketchbook "digital portfolio" has broaden the students' design universe to utilise the design tool to digitally merge design ideas created at different time intervals of the design process.

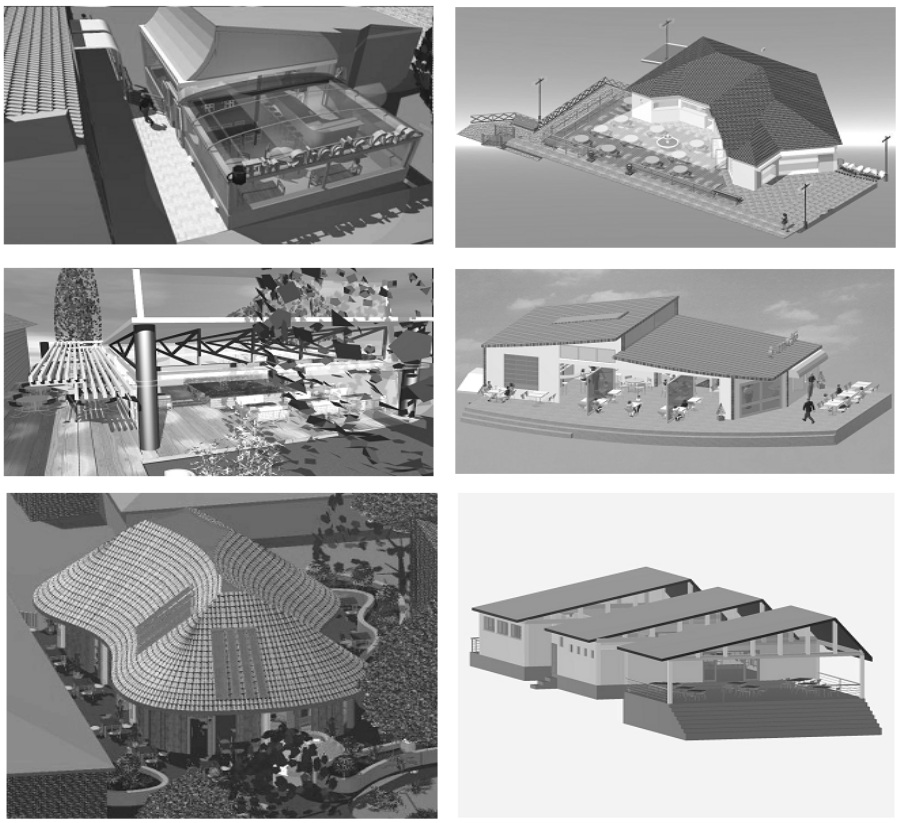


Figure 2. Some examples of first year design computing students' ideas in designing a café produced at the paperless design computing studio.

4.2 COMMUNICATION AND REPRESENTATIONS IN A PAPERLESS DCS

The newcomer to a paperless design studio might expect instant efficiency as a result of the move to digital design studio. Yet, even after developing a basic fluency with a given program, this efficiency is not likely to be immediate. Initially, a significant amount of time must be devoted to mastering computing in the design context. It is important to anticipate the "time sink" at the early stages of the digital engagement and to allow for it (Lewis and Wojtowicz, 2001).

The forms of representation in the traditional design studio have been the use of physical models, manual drawings, and even to some extent two and three-dimensional CAD drawings. In a paperless DCS using design tools as tools for inquiry there were various types of representation forms produced by our students at the paperless DCS including, real-time modelling, web-based presentation, dynamic presentation incorporated with sound, QTVR animations and walk-throughs. A promising aspect of the digital model lays in its inherent ability to be used as data for the production of design and to serve as date in CAD-CAM, or the quick prototyping process. This can potentially create a new relationship between designer, project and object of design, perhaps turning the designer into the digital artisan-craftsman. The nature of the digital design medium permits the designer to think more naturally in three dimensions and to a greater degree than previously imagined.

4.3 PAPERLESS DCS AND ITS IMPLICATIONS FOR STUDIO PEDAGOGY

The nature of design with its uncertainty and irregularities are congruent with the epistemology and ontology of the constructivist pedagogy. The inclusion of constructivist ideology within the paperless DCS helps to increase learning and advance constructions of knowledge (Powers, 2001). Similar to a traditional design studio the responsibility in the learning process is shared and negotiated amongst teachers and learners. Utilising digital media in a paperless DCS enriches the design studio environment with a multiplicity of informational sources and representations that help students and teachers reflect upon design ideas at different time intervals at the early conceptual stage of the design process. The paperless DCS is an excellent place for the outgrowth of exploring, investigating and constructing design ideas and is congruent with the epistemology and ontology of the constructivist pedagogy.

5. Discussion

In the paperless DCS there were different types of interactions that took place between the students and the design tools, between the students themselves and between the students and their design instructors and teachers. The focus on the interaction between the student and design tools in the paperless DCS distinguishes the approach presented in this paper rather than using computers as generative systems. The generation of shapes using generative systems is very different with the creation of design ideas within a form of fruitful dialogue between the student and the design tool where designing as an activity occurs with the active participation. Designing with computers is not a systematic process by which a set of rules would generate design solutions (Madrazo, 1999). Designing with computers is rather a situated process wherein the result of design artefacts is based on the design situation that each student encountered, the state of interaction with the design tool and which objects primitives of the design tool the student were utilised. A designer, through analysis, investigation, research and interaction begins to synthesise an idea for a possible solution to the challenge of the situation at hand. The process is then to chase this idea down to see if it works, to test it, to modify it, to branch out in a different direction or to reject it back all together.

References

Lewis, M. and Wojtowicz, J.: 2001, Design in the new media: Digital design pedagogy at the SoA, University of British Columbia, ECAADE 2001: Architectural Information Management, Helsinki University of Technology, Helsinki, pp. 256-261.

Lynn, G.: 1999, Animate Form, Princeton Architectural Press, New York.

Madrazo, L.: 1999, Types and instances: a paradigm for teaching design with computers, Design Studies, 20 (2), 177-193.

Muir, E. and O'Neill, R.: 1994, The paperless design studio, GSAP, News Line Statement, http://www.arch.columbia.edu/DDL/paperless/NEWSLINE.html.

Norman, F.: 2001, Towards a paperless studio, Proceedings of The ARCC Spring Research Meeting Architectural Research Centers Consortium, The College of Architecture and Urban Studies at Virginia Tech, Blacksburg, Virginia, pp. 85-91.

Powers, M.: 2001, Applying a constructivist pedagogy to design studio education, Proceedings of The ARCC Spring Research Meeting Architectural Research Centers Consortium, The College of Architecture and Urban Studies at Virginia Tech, Blacksburg, Virginia, pp. 78-84.

Resnick, M.: 1996, New paradigms for computing, new paradigms for thinking, in Y. Kafai and M. Resnick (eds), Constructionism in Practice: Designing, Thinking, and Learning in a Digital World, Lawrence Erlbaum Associates, Mahwah, N.J., pp. 255-267.

Schmitt, G.: 1997, Design medium-design object, Keynote, in R. Junge (ed.), CAAD futures 1997, Kluwer Academic, Dordrecht, The Netherlands, pp. 3-13.

LEARNING THROUGH STRUCTURAL ACTIVITY IN COLLABORATIVE COMPUTER-AIDED DESIGN

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Abstract. The role of structural activities and other solution searching activities in design learning and problem solving have been identified in laboratory studies of problem solving and also in case studies of design teaching.. In laboratory studies, students have solved creative problems collaboratively under various communication conditions. The case studies follow students working on the same problem under two conditions – one group is taught using traditional face-to-face teaching while the other group is additionally supported by a text-based web board. This paper review findings from three experiments from which we can see that students producing above average solutions involved more structural activities than the mediocre cases. These successful cases engaged in textual expression of their design solutions. Computer tools for design should therefore support multiple representations of design work.

1. Introduction

Computer support for collaborative design has focused largely on the synchronous communication of graphical information, supported by file exchange and video channels in addition. The use of these tools has been reviewed and the assumptions challenged. Collaborative design can be better understood as asynchronous and synchronous activities together in which a number of communications channels can be beneficially employed, with video and synchronous drawing often inhibiting creative output (Kvan 1997, Vera et al 1998). The role of representational modes in CAAD other than graphics has been review elsewhere (Lawson & Loke 1997). The need for a more diverse range of design learning support in virtual studios therefore deserves more attention. The concept of structural support of design has been explored and finds relevance in the specification of virtual design environments.

Problem solution is affected by problem perception (Newell & Simon 1972). The uniqueness of design as a problem solving activity lies in the possibility of unlimited number of solutions (its ill-formed nature) in contrast to the well-formed nature of a geometric problem, for example. The range of design solutions presented in a class can therefore vary drastically if students frame their understanding of the problem in different ways. In the sequential nature of design exploration (i.e. time sequential, not thought sequential, the framing of earlier problems will have an effect on later sub-problems (Akin 1986). Appropriate problem representations can aid the identification of creative solutions (Holyoake 1984). Some representations will be more effective than others (Mumford et al 1994). These findings are confirmed in design research, re-representations of design concepts and solutions are essential to successful design (Goldschmidt 1997, Eisentraut 1999). Such representation allows for concepts to be compared, joined, transformed or interpreted. In studio learning terms, this implies that re-representation supports better understanding of the design problem at hand.

If this is the case in design tasks, can the findings help us in our preparation of collaborative design environments intended for learning? With a growing interest in virtual design studios between different universities (as demonstrated in the proceedings of almost every CAADRIA, eCAADe or ACADIA conference in the past ten years) and the development of online virtual teaching environments (Maher Simoff Gu & Lau 2000), we need to consider the tools made available to participants in the collaborative design learning context. To this end, three sets of experiments have shed light on the tools we might include.

2. Collaborative Problem Solving

Collaborative online design exercises are established in schools of architecture with a number of intended outcomes: exposing students to the new working environment of online collaboration; supporting off-campus learning; increasing cultural exposure (Bradford et al, 1994; Maher Simoff & Cicognani 2000). To this, we can also add the opportunity to learn more effectively (Kvan Wong & Vera 2002). Before identifying implications for collaborative design learning environments, let me first summarize relevant recent experimental findings from our recent research.

2.1 IMPROVING INITIATION OF DESIGN IDEAS

An earlier study of architectural design was reported in Kvan Yip & Vera (1999). In this study we investigated the relative roles of textual and diagrammatic representation in a collaborative design task. Two different conditions are established. In one, the participants are asked to communicate

by chat line and are allowed to draw on a whiteboard as they seek to collaboratively resolve the design problem. The product of this collaboration is a sketched solution. In the second condition, the participants are asked to explore the design and come to a proposal only through the chat line, then write up a proposal in text form. Those in the text only condition were given an additional 5 to 10 minutes after the experiment to translate the text description into a diagram without modifying their ideas, allowing us to confirm that a shared understanding had been arrived at in text mode. We could also then compare the final drawing with those in the other condition. With this setup, we seek to identify the effects of text versus diagrams in the collaborative design task when the bandwidth is limited to 'chat-line' conditions.

The full details of the research conditions have been described elsewhere. In the course of the experiment, communication protocols were collected. The protocols of these experiments were coded by the authors to identify the initiation of ideas during design collaboration. To do this, protocols were coded to identify when new ideas were introduced into the communication. New ideas were defined to be (1) an idea not yet mentioned; or (2) a fundamental reinterpretation of an idea in play. Table 1 shows the raw number of initiations and total communications during the experiments.

Table 1: Initiations of ideas
(total communications in parentheses)

Diagram allowed	Text only
3 (61)	10 (90)
4 (55)	21 (105)
	13 (82)

From this encoding, it was found that chat line participants explored more ideas (% ratio of high level exchange initiated by subjects in the chat line conditions is larger than that of those in the audio condition in general) than those using video/audio. Thus, chat line appeared to promote a richer exploration of the design problem space than video/audio environments.

2.2 IMPROVING LEARNING

While demonstrating the non-graphical communication can improve the generation of design alternatives, is there any reason to believe that such communication can affect learning. This postulation is supported by the work of Yip (2000) in which she investigates the effects of learning in the solution of isomorphic logical problems, not design problems. In her studies, she adopted isomorphic Tower of Hanoi and Monster and Globe problems

(Kotovsky Hayes & Simon 1985). Subjects were paired to work collaboratively in either text or diagrammatic conditions. Since the problems are isomorphic, it is possible to examine whether any learning has occurred when the pairs solved the second problem. The results demonstrate that the text only condition was better for solving these problems and, most importantly, that the text only condition showed clear support for learning. Subjects using the text-only condition formed better hypotheses, made fewer wrong moves and violated fewer rules than those working in the other condition while solving their second problem. This set of experiments illustrated that the text condition supported learning.

2.3 IMPROVING STUDIO LEARNING

Taking these experiments into the design studio itself was the next step. As reported in Kvan Wong & Vera (2002), a design studio was established in which students were formed into two groups and a design studio problem given as part of the normal sequence of second year undergraduate studio teaching. The same design topic was given to both groups. Teaching was conducted in the normal manner of design studio – desk reviews, pin ups, individual and group discussions (Schön 1985). One group was supported in addition by a web board that was used for daily communication between tutor and students as well as between students themselves. Access to the board was freely available and all postings visible to all participants in the second studio group.

At the end of the studio session, design products from both groups were independently evaluated; no difference was found in the results, suggesting that both groups were able to complete the work equally as well. The students in both groups were interviewed extensively throughout the semester as well as at the conclusion of the project. The web board supported group used text extensively in their work, although not uniformly. Some students used more text that others, both in their web board communications and also in other media such as annotating paper based drawings. We analyzed the use of text in all its forms more extensively and identified two important findings from these observations: the students who used text examined more alternatives (as suggested by findings noted in 2.1 above) and they exhibited better learning than those who worked only in the conventional studio mode of sketching and drawing. Text had been used by the students as a tool of re-representation and exploration; those who explored more ideas and re-represented these ideas more often appeared to have better design results than those who simply drew and talked with their tutor (in agreement with Fricke 1999).

3. Implications for Online Collaboration

Structural activity can be defined as the restructuring of ideas and meaning through representation. From the work described above, structural activity is an essential part of successful design work. Learning appears to be reinforced by structural activity. Computer-supported collaborative design environments do not enable a rich variety of structural activity due to their restricted range of tools and working processes supported. Thus, we can reconsider virtual design studios to improve learning opportunities.

What do these experimental and studio results suggest to us for computer-supported collaborative design environments? First, it suggests that synchronous audio / video environments are not supporting learning as well as those in which students have to describe in words their intents. Secondly, computer tools that are focused on graphical representations, such as conventional CAD systems or sketch tools, must be supplemented by non-graphical tools. Thus, the environment for learning design collaboratively across a computer network should not be a simple replication of the face-to-face environment but should take advantage of the opportunity to reinforce learning. The tools should support learning and design development through the structural activity of re-representation. While most students may do this through making models, in an online collaborative world this is not so easy. The modes of communication available to us reinforce the value of textual communication as a means of re-representation.

It is not easy to use this combination of tools. In face-to-face teaching, tutors can switch between modes of verbal description and graphic representation without effort. Asynchronicity makes this less easy; we do not have tools to record oral descriptions while we drawn. Importantly, though, as Olson (1996) notes, written text requires more substantial consideration of the meaning and is a better support of learning. It suggests that three aspects of virtual studio planning deserve attention: the selection and configuration of tools to be provided; the specification of the design problem to be attempted; and the sequencing or phasing of activities during the studio period. Each of these should accommodate the need for multiple media and present opportunities for restructuring of the design solution. A phased studio can be composed to support a phasing of tasks, leading students more carefully through steps of design exploration from initial exploration through to design presentation, explicitly requiring them to describe the design in many modes rather than remaining in the graphic world.

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References

Akin, O.: 1986. Psychology of Architectural Design. London: Pion.

Bradford, J. B. Cheng N. Y. W. Kvan, T. 1995 The Virtual Design Studio *Proceedings ECAADE'94*, University of Strathclyde, Glasgow 1994, pp. 163-167

Eisentraut, R.: 1999. Styles of problem solving and their influence on the design process. *Design Studies*, 20(5), 431–437.

Fricke, G.: 1999. Successful approaches in dealing with differently precise design problems. *Design Studies*, 20(5), 417–429.

Goldschmidt, G.: 1997. Capturing indeterminism: representation in the design problem space. *Design Studies*, 18(4), 441-445.

Holyoak, K. J.: 1984. Mental models in problem solving. In *Tutorials in learning and memory*, J. R. Anderson & K. M. Kosslyn (Eds.), New York: Freeman.

Kotovsky, K., Hayes, J. R., Simon H. A.: 1985 Why are some problems hard? Evidence of m Tower of Hanoi *Cognitive Psychology* 17 248-294

Kvan, T., Wong, J. T. H., Vera, A. H.: 2002 The Contribution of Structural Activities to Successful Design, *International Journal of Computer Applications in Technology* in press

Kvan, T., Yip W. H. and Vera, A.: 1999, Supporting Design Studio Learning: An investigation into design communication in computer-supported collaboration. In *Proceedings CSCL'99*, Stanford, December 1999, pp 328-332

Kvan, T.: 1997 But is it collaboration? In *Challenges of the Future*, ed. B. Martens, H. Linzer & A. Voigt. eCAADe '97, p. 5. Vienna: Österreichischer Kunst- und Kulturverlag, 1997, (CD ROM publication)

Lawson, B. & Loke, S. M. : 1997 Computers, words and pictures. *Design Studies*, 18, 171-83

Maher, M. L., Simoff, S., Gu, N. and Lau, K. H.: 2000 Designing virtual architecture, *Proceeding of CAADRIA2000*, pp. 481-490

Maher, M.L., Simoff, S., and Cicognani, A.: 2000. Understanding Virtual Design Studios, Springer-Verlag, London

Mumford, M. D., Reiter-Palmon, R. & Redmond, M. R.: 1994. Problem construction and cognition: applying problem representations in ill-defined domains. In M. A. Runco (Ed) *Problem Finding, Problem Solving and Creativity*. Norwood, NJ: Ablex Publishing.

Newell, A. & Simon, H.: 1972. *Human problem solving*. Englewood Cliffs, N.J.: Prentice-Hall.

Olson, D. R.: 1996 Towards a psychology of literacy: On the relations between speech and writing *Cognition* 60 83-104

Schön, D. A.: 1985. *The Design Studio: an exploration of its traditions and potentials*. London: RIBA Publications Ltd.

Vera, A. H., Kvan, T., West, R. L. & Lai, S.: 1998. Expertise, Collaboration and Bandwidth. *Proceeding of CSCW '98*, Cambridge MA, ACM Press, 18-23.

Yip W. H.L: 2000 *The relative functions of text and drawing in computer supported collaborative problem solving*, M Phil Thesis, University of Hong Kong, unpublished.

TEACHING CONCURRENT ENGINEERING USING INTENSIVE INTERDISCIPLINARY ROBOTIC WORKSHOPS

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Abstract. The métier of architecture is, contrary to the myth of the single visionary architect, one of co-ordinated interdisciplinary teamwork. For students of architecture, this concept can be somewhat abstract without the chance for hands-on experience in working in such teams. The authors contend that this type of co-operation is better trained than taught. As a consequence, the authors have sought to create a pedagogical framework for training interdisciplinary work: Furthermore, by using assignments that call for concurrent engineering, the framework allows students to understand the complexities of integrated planning practices. The paper explains the methods and results of workshops carried out at two Universities over the past one and one-half years. Students are arranged in small teams of 3-5 students consisting optimally of architects, engineers and computer programmers. The assignment is to build and program a robot to successfully execute a prescribed set of objectives. The 10-day workshop is carried out as a competition in order to accelerate the development process and to focus the design work to a specific goal.

1. Architecting

One of the most daunting challenges for young Architects is acclimatising themselves to the world of practice upon finishing their studies. Alongside the practical application of technical and aesthetic rules, young architects must also learn how to work in teams. When these teams are made up of likeminded architects, the teamwork is relatively straightforward. However, when these teams consist of interdisciplinary members, the assumptions of the architect often are met with confusion if not scepticism. Indeed, the different methods of problem solving across various disciplines contribute a great deal to both the richness and difficulty in working in interdisciplinary teams. The author contends that learning to work in these teams cannot be

taught; it must be trained.

These interdisciplinary teams are also confronted with rather complex design problems. In fields parallel to architecture, namely shipbuilding (where large design teams produce one-off solutions for individual clients) a practice entitled concurrent engineering has been developed. This process of concurrent problem solving has also been termed "architecting" by Rectin. Architecting is the process by which large problems are broken down into smaller problems that are then solved in parallel using heuristics. This process, like working with interdisciplinary teams, is also thought to be better trained than taught. To date, few didactical concepts have attempted to train students of architecture and engineering in these real world practices. For this reason, tutors from the Institute for Industrial Building Production (Faculty of Architecture), the Institute for Process Control and Robotics (Faculty of Computer Science) and the Institute for Machine Tools and Manufacturing Technology (Faculty of Mechanical Engineering) undertook to create a design workshop to enable students to gain initial interdisciplinary experience.

2. Workshop: “I, Robot”

A group consisting of computer scientists, mechanical engineers and architects have attempted to fill this gap by offering an intensive workshop in which a non-trivial design problem is to be solved by mixed teams from all three disciplines. It must be stated that one of the largest hurdles to creating a workshop that spans various faculties is the problem of accreditation in the various faculties. Further, ensuring that the students are all at the same level in their various faculties had to be considered. Despite these administrative hurdles, the three faculties were able to offer a common design workshop. The timetables of the different faculties also prescribed a two-week period in which the workshop could take place.

The design problem was to construct and program a robot, which must competitively complete a prescribed course. Naturally, the field of robotics is a branch of engineering in itself. The organisers sought to use this design problem because of its relationship to each individual faculty. Furthermore, the steadily increasing presence of robotics in the society made the topic timely. In order to allow for some measure of success within the two-week time constraint of the workshop, the organisers sought to reduce the complexity of the task. The students used the Lego Mindstorms robotic system as the physical basis for the project. Each group was given an identical set of Lego pieces including the RCX "brick", sensors, motors and various Lego pieces. The rules stated that no other materials were allowed. Each Mindstorms Robot set included two touch sensors and one light sensor

as well as an infrared transceiver for downloading the programs and communication between the robots themselves.

Although the Lego system comes with a simple and easy to learn programming environment, this language is limited by having essentially no variables and no sub-routines. For this reason, the students were instructed to use the NQC programming language developed by Dave Baum. [BAUM1999] NQC stands for Not Quite C and the language employs higher level programming features akin to the C programming language while providing specific commands to ease the input and output aspects of programming for the Lego Mindstorms robotic chip-set. In total 50 students took part. Twenty students each from computer science and architecture and ten mechanical engineers were divided into ten teams of five persons each. Each team had to include at least one student from each faculty. Additionally, each group was responsible for sending one member each to five inter-team committees. The committees were established to emphasise the co-operative nature of the entire exercise. The five committees were assigned the following decision areas:

1) Constructors' Committee: this was the main forum for discussing issues among the teams.
2) Communication Committee: the committee was responsible for establishing the rules for inter-robot communication as well as the protocols to be used.
3) Race Committee: the race committee established the rules of the competition such as when a robot could be touched.
4) Code Committee: the code committee was responsible for the type and placement of light and dark areas on the floor of the race area, which could be used by the robots to establish place or direction.
5) Inventory Committee: although the construction of the robots was limited to the Lego Mindstorms Kits, the teams were allowed to trade among themselves and this committee was responsible for documenting and approving all trades.

The realm of each committee often overlapped or influenced other committees. This entailed a lot of discussion and communication, which was part of the process. Disputes went first to the Constructor's Committee and if they could not be resolved there, then the Grand Organising Directors (GODs), made up of the three Tutors, collectively made a decision for the entire group.

3. Assignment

The race or assignment itself consisted of three parts. The initial phase

involved finding a path through a labyrinth. The second part of the course involved sending a token through an infrared transceiver to another unknown robot. Upon receipt of the token, the robot then had to calculate which one of two doors to pass through. The third part consisted of a simple course where raw speed played a role. The course was delineated with particleboard barriers with sides 10 cm high. This allowed the teams to use the touch sensors to feel their way through the labyrinth and to concentrate the light sensor on the floor where white and black paper was used to codify instructions. It also allowed a clear overview of the course and a barrier to prevent the robots from going astray.

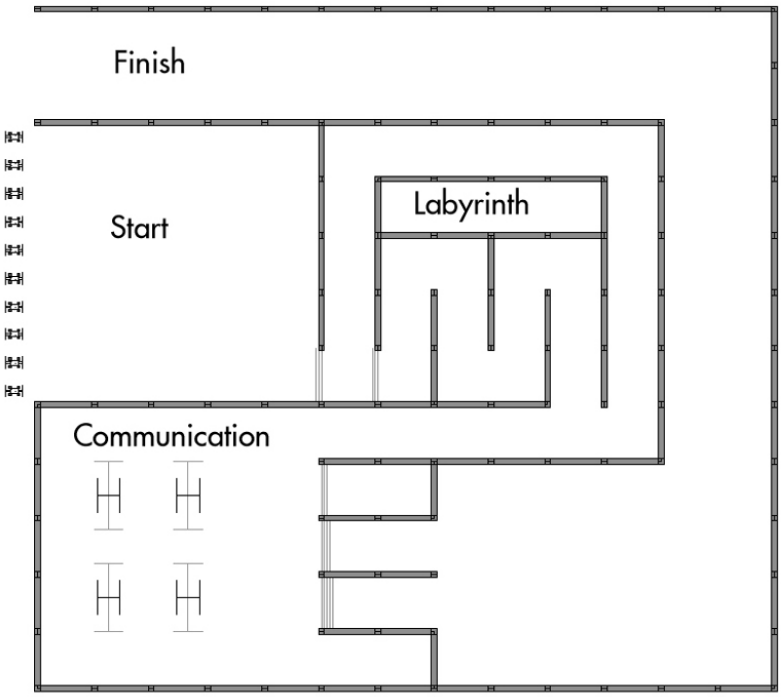


Figure 1. Plan of the Race Course.

The initial impression that the engineers would design the robot, the computer scientists would program it and the architects would pick the colours soon dissolved under the complexity of the task. While the labyrinth was relatively straightforward, it must be remembered that all ten robots undertook the course simultaneously and so inputs to the touch sensors could not be relied upon to be static aspects of the course. Furthermore, the designing of a robot is a task that requires concurrent engineering as the software must be developed parallel to the physical layout of the robot all the while trying to meet the higher level goals of the race assignment.

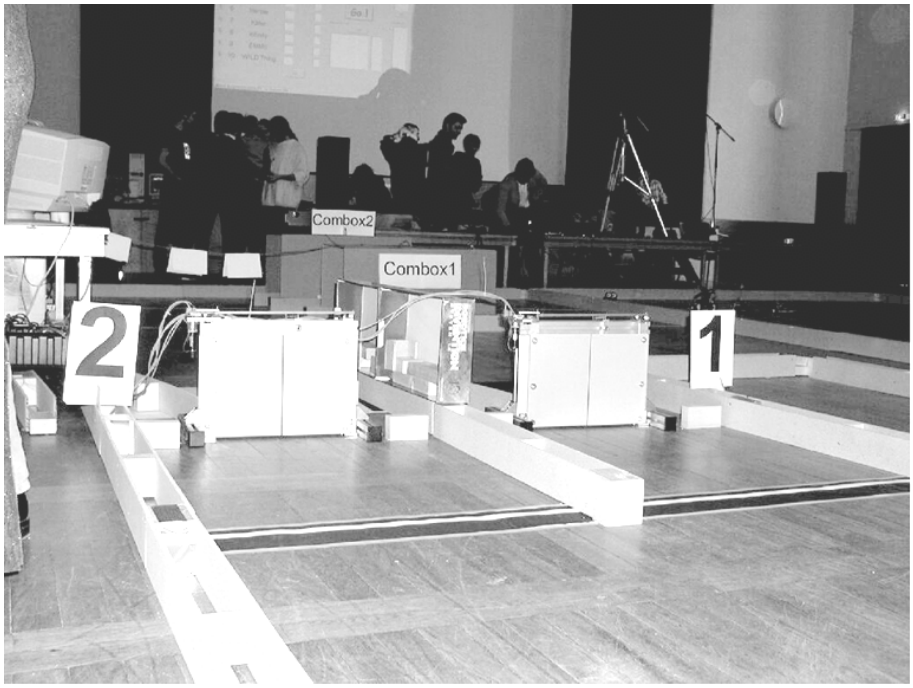


Figure 2: Detail of the Course and computer controlled doors between Sectors 2 and 3

The workshop began with two days of lectures and team-building exercises. General aspects of robotic engineering as well as current issues in robotics were followed by a lecture dealing with the pragmatics of software design using NQC. A third lecture illustrated various modes of locomotion and steering. At the second half of the second day, the teams were set and the committees formed. After the members of the Inventory Committee were appointed, the teams received their Robotic Kits. The two day wait helped to raise the suspense and to create an air of expectation akin to the way a pilot will "stand on the brakes" before starting a long take-off run.

The following five days consisted of counselling in the mornings and free design and development time in the afternoons. The entire group was given a room to collectively develop their designs. This allowed an increase in the "technology transfer" between teams and also facilitated impromptu meetings of the various committees. A couple of the teams attempted to work at their dormitories, however, these teams were quickly unaware of committee decisions and so returned eventually to the workspace.



Figure 3: One of the ten interdisciplinary teams

The final three days saw a schedule akin to a formula one weekend. The third to last day was used for time trials on the course and for small design adjustments. The penultimate day was highlighted by a qualifying session in order to determine which group started from which position. The race itself took place in a one-hour period on the last day. Despite last minute hiccups and some frantic programming up to five minutes before the start, the race was held and with some success.

All of the teams were able to complete the labyrinth. The communication part of the race was somewhat more difficult due mostly to the robots being shunted whilst communicating with one another. This led to a breakdown in the token exchange and the robots then restarted their search and communicate routines. Due to the presence of ten Robots in the communication field, the chances were high that a robot pair would be interrupted. Nonetheless, four robots did make it through to the doors and were able to send a correct signal to the listening computer, which then opened the appropriate door.

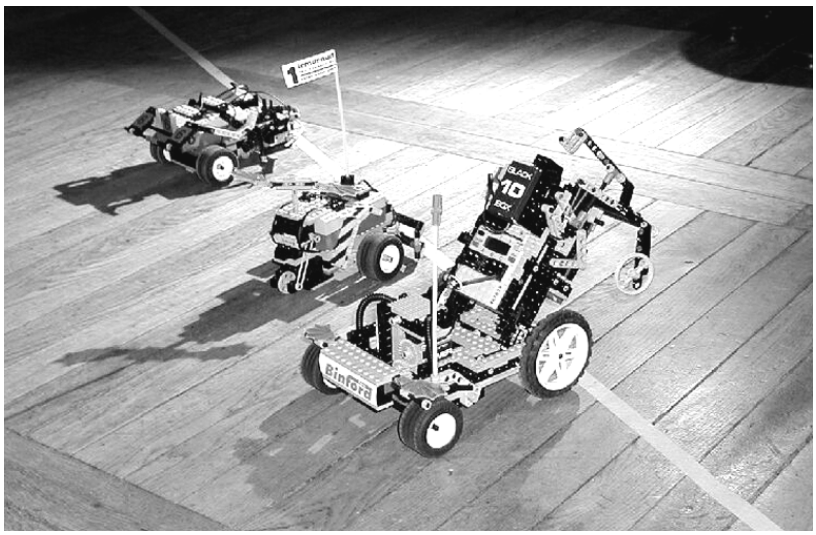


Figure 4: Three different concepts



Figure 5: The Start of the Race

Post race, the students were asked to describe their experience in working in the group and with their success in meeting the assigned task. Almost universal was the positive experience of having worked with students from other faculties. Furthermore, the competitive quality of the workshop was a

strong motivating factor when they met with design problems. Although the assignment appeared easy at first, the newness of programming, the tight time schedule and the nature of collectively carrying out a design task in an interdisciplinary group all combined to complicate the challenge. Subsequent demand has led to two further inceptions of the Robot Workshop with similar results.

References

Baum, Dave: Lego Mindstorms Roboter. Bonn, Galileo Press, 2000. ISBN 3-934358-39-x

Knudsen, Jonathan B.: The Unofficial Guide to LEGO MINDSTORMS Robots. Sebastopol, California, O'Reilly & Associates, 1999.

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