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A New Perspective of Transforming the Use of CAAD in Designing the Built Environment

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Abstract:

This paper introduces a new perspective of transforming the use of Computer Aided Architectural Design (CAAD) in designing the built environment. This perspective conceives the design process of the built environment to be an integration of technical and social processes. Virtual Design Environments (VDEs) open exciting new territory and have the potential to advantage the design of the built environment. The technical dimension of this perspective can be accomplished by developing an intelligent and interactive VDE for architectural design through providing interactive counterparts (virtual observers, e.g. intelligent design agents) to the designer to offer useful assistance in designing by supporting behaviour and semantic-based concepts within VDEs. The social dimension is provided by offering a conduit between multiple human opinions and information sources to offer instructive, constructive design suggestions. This is reflected in the interactions within the VDE between the designers, clients, community and planners. This paper introduces a framework of intelligent and collaborative 3D virtual environment that has the potential to transform the use of CAAD in designing the built environment at the conceptual stage of designing.

1. Introduction

Design is a complex cognitive process which involves creative skills, artistic intuitions, as well as a rich repertory of knowledge. Furthermore design is not description of what is, it is exploration of what might be (Mitchell, 1990). Computer Aided Architectural Design (CAAD) is a process where the designer and the computer are expected to work together to produce a design solution. The creative ideas of the designer are transformed into a design, with the help of CAAD tools. CAAD uses the computer primarily as a design medium. The presence of useful CAAD at the conceptualisation stage of designing has yet to be witnessed. The use of CAAD in designing the built the environment seems rather primitive and limiting even after more than three decades. At the conceptualisation stage of, designers generate design ideas and concepts to meet certain requirements of the artefact to be designed. So far, designers utilise their creative skills and uses their architectural knowledge, imagination and judgment to generate ideas and the computer is used mostly at later stages to present and document these design ideas and might be used to carry out systematic reasoning. Hence, the value of "the designer and the computer working together" has not been fully experienced by architects.

The promise of CAAD has been that it will play a vital role in the entire design process. In the last 40 years, one can claim that CAAD has replaced the drawing board for design representation, but did not have a great influence on the design process itself or on the designed products. CAAD is dealt with in such a way to allow the designer to document the design into the computer and to analyse the design product. Through the evolution of CAAD systems, the representations are increasingly complex and powerful. Different components can be composed carrying and increasing amount of semantic information. From the phenomenological perspective (Turk, 2001) one of the reasons of less successful use of CAAD in designing is not accommodating the interaction between the actors in the design process including architects, engineers, engineers, clients and council planners. The goal of communication is not to share some information but to engage the listener into some action or activity. This paper proposes an approach which facilitates human-machine collaboration and human-human collaboration within an intelligent design system. The intelligent design system plays the role of design assistant within an interactive and collaborative 3D virtual environment.

2. Collaboration in Design Teams

The content of the evolving design depends heavily upon negotiation strategies and other more subtle and ubiquitous social processes that shape design work. Design emerges from social interaction. Team members' orientation to a solution or process is demonstrated by levels of commitment in utterances and gestures. Depending on their level of commitment and other team members alignment they adopt appropriate strategies of persuasion. They carefully moderate their commitment to their ideas to remain amenable to negotiation. They appeal to common sense, design theories, standard practices, expert practices, user preferences. Many solution proposals and interpretations of requirements clearly arise from designers' interaction. They also emerge as part of the ongoing activity (Brereton et al, 1996).

As the design team negotiates the problem space, each designer makes bids to have issues they think important discussed by the team. Having called focus on an issue, the other designers might engage in the focus adding ideas toward a partial solution. The content of design evolves then through discussions adding incremental solution additions, use scenarios, justifications and information seeking questions. The designers acknowledge other contributions. They align themselves with various aspects of the evolving solutions and approach and distance themselves from others.

Design projects are typically comprised of "design stakeholders" equally invested in, and respectful of, each other's success. Collaboration fosters true innovation when there are no hidden agendas or fear of questioning the way things have always been done. In design, projects are often initiated without a clear roadmap of desired expectations and outcomes. Charting the project's aesthetic, financial and programmatic intentions will ultimately achieve the goals of the stakeholders, and reinforce the benefits of collaboration. The reality of the collaborative design process is that, unlike the predictability of, for example, a manufacturing process, the design process can be infuriatingly nonlinear. It can be likened to more of a patient search. Every project has a unique set of circumstances or "reasons for being" when the team is committed to the

potential of innovation. Playing collaboratively fosters a dialog resulting in something larger than playing individually (Brereton et al, 1996).

3. Collaborative Virtual Environments in the Built Environment

Virtual Environments (VEs) are increasingly offered as environments for design. Using VEs to visualise ideas from the initial steps of design, the architect is challenged to deal with perception of space, solid and void, without translations to and from a two dimensional media. Networked virtual environments allow several users distributed over a network to participate in a common virtual environment. Virtual environments provide the opportunity to present a large amount of information.

Information sharing is central to collaborative work. Collaborative VEs can help with information sharing and communication tasks because of the way in which they provide a context for communication and information sharing to take place. Collaborative VEs are distributed virtual reality systems that offer graphically realised, potentially infinite , digital landscapes. Within these landscapes, individuals can share information through interaction with each other and through individual and collaborative interaction with data representation (Churchill, Snowdon and Murno, 2001). An example of a collaborative virtual environment at the University of Sydney is shown in Figure 1. This environment supports shared context, awareness of others, negotiation and communication, and flexible and multiple views.

It is argued (Churchill, Snowdon and Murno, 2001) that collaborative virtual environments must go beyond being “cool” and having aesthetic appeal. The computational value for efficiency, visualisation and communication are evident in many advanced CAD systems in which 3D models can be generated, rendered and animated. 3D Virtual Environments in design domains have been able to mimic the spatial configuration of physical worlds, changing the role of CAD systems, partly, from being drafting tools to producing the building blocks of these new environments (Maher et al, 1999). Virtual Environments provide powerful communication and navigation environments within which users and designers interact either in asynchronous or

synchronous mode within centralised or distributed environments or share their designs, knowledge and experiences. VEs allow designers to visually walk through, inspect and present the designs in immersive 3D environments at the proper size and scale.

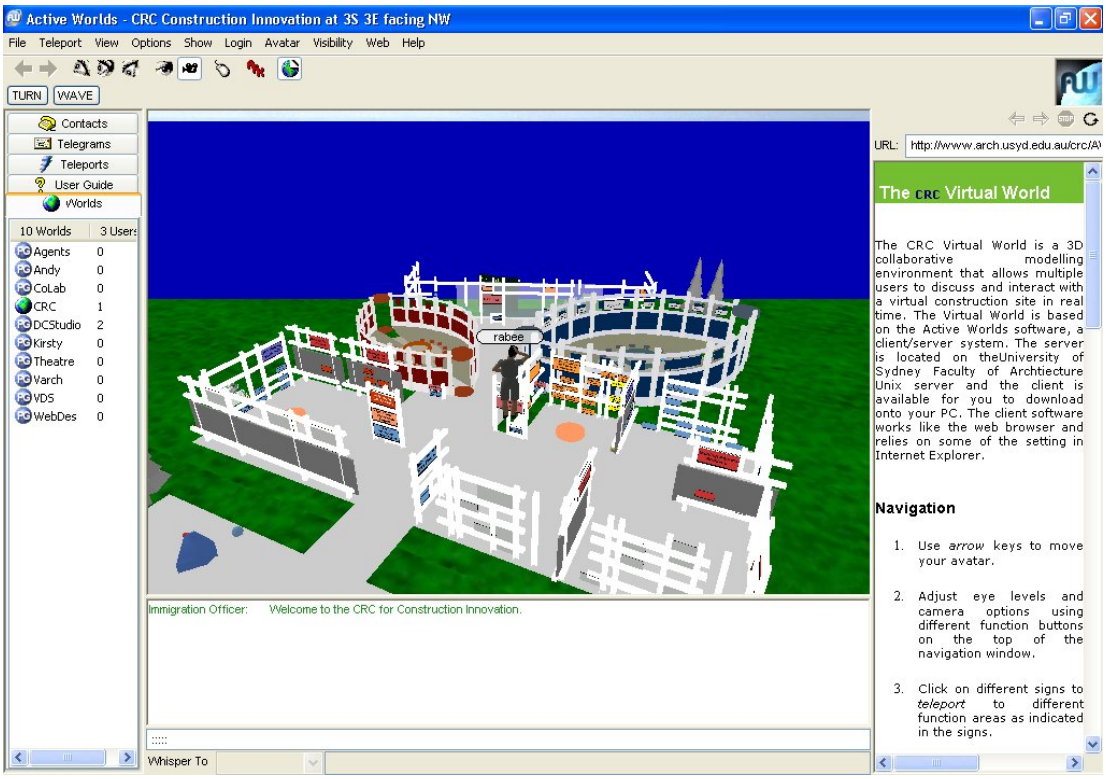

Figure 1. An example of a collaborative virtual environment at the Faculty of Architecture, University of Sydney.

The ability to design interactively, test the consequences of actions and to explore different ways of solution refinement is crucial in design and architecture. A design medium that provides such capabilities would benefit the experienced designers and strengthen the novice designer's ability to gain depth in designing. 3D Virtual Environments (VEs) are currently used as visualisation tools for communicating design ideas and teaching tools for design education. However, VEs have the potential to reach beyond the limitations of CAD systems and can be utilised as design tools for architecture (Beckmann, 1998).

4. Transforming the Use of CAAD in Designing the Built Environment

This paper introduces a new perspective of transforming the use of CAAD in designing the built environment. This perspective conceives the design process of the built environment to be an integration of technical and social processes. Virtual Design Environments (VDEs) open exciting new territory and have the potential to advantage the design of the built environment. The technical dimension of this perspective can be accomplished by developing an intelligent and interactive VDE for architectural design through providing interactive counterparts (virtual observers, e.g. intelligent design agents) to the designer to offer useful assistance in designing by supporting behaviour and semantic-based concepts within VDEs. The social dimension is provided by offering a conduit between multiple human opinions and information sources to offer instructive, constructive design suggestions. This is reflected in the interactions within the VDE between the designers, clients, community and planners.

The combination between virtual environments and intelligent agents has given rise to a new area at their meeting point, which is called intelligent virtual environments. The potential benefits of employing intelligent agents in virtual environments include empowering computers not only to support a much higher degree of visual realism but also with processes of intelligent behaviour. Research in the field of virtual environments is moving towards intelligent virtual environments in order to include specific options of functionality; e.g. researchers in the field of artificial life have even more ambitious aims. These aims include the creation of virtual worlds containing digital life with new rules but not necessarily similar to those of real world. Some see distributed interactive virtual environments such as Active Worlds as a basis for the development of such virtual worlds allowing autonomous interaction between artificial life forms and virtual worlds (Aylett and Luck, 2000).

Agents collaborate with human designers, and they cooperate with each other seamlessly to achieve a given goal. Some agents are reflections of the cognitive inner workings of a person while others are computational because they take care of detailed design works such as constraint processing, search, and data visualisation. Humans live in a stimulating

and dynamic environment which allows them to be creative and productive. But there are limitations of humans especially in terms of cognitive and mental power. For instance, it is currently known that in short term memory, there are only 4-7 conceptual chunks we can hold (Moran et al, 1983). We often have trouble visualising a set of vectors in three dimensions, let alone doing so in higher dimensions. With the fast growing technology in computer industry, we have become accustomed to using machines as our cognitive and computational prostheses (Pu and Lalanne, 1996). That is, we rely on their power to help us accomplish tasks. The approach here is to use the idea of intelligent agents as the interface between human and machine. Sociologists maintain that the interaction between human and machine is mainly a social one (Nass et al, 1994). Furthermore, the anthropomorphism brought by human-like agents is superior than other metaphors such as object-oriented programming.

4.1 Integrating intelligent agents in collaborative virtual environments

In order to successfully integrate intelligent autonomous agents in the context of virtual environments, a number of issues should be addressed. The framework should permit agents to use its knowledge to explain tasks and observe designers actions, as well as allowing the agents to perform actions at their discretion. In contrast, current agent frameworks focus on execution. They are not able to explain to the users what they are doing nor recognising what other agents or users are responding to (Norman, 1994). The framework of intelligent agents should allow agents to act both reactively and in a goal directed manner. Hence, the agents' actions will be relevant both to the task at hand and to the current state of the environment. At the same time the agent must be able to perceive the virtual world as well as control its realisation in the virtual world with the ability to manipulate objects in the world.

The situated action approach to agents allows them to perform in different situations by changing their focus and situating themselves in the new situation. Such agents will exhibit situated behaviour. This is unique compared to specifying agent's behaviour by means of production rules. Encoding task behaviour as production rules denotes that the behaviour of such agents will be deterministic. The situated goal-based agent acquires its

knowledge from: the situations it encounters, the environments it interacts with and designers' actions within these environments.

4.2 A Framework of Intelligent and Collaborative Virtual Design Environment

The proposed framework of a multi agent system to support designing in virtual environments is organised in a two-tiered structure comprising design tools and design semantics support. The design tools tier focuses on enhancing the interface of virtual design environments by introducing adaptable design objects to facilitate the development of architectural designs. The adaptable design objects include walls, doors, windows, floors, slabs, roofs, stairs and furniture. These objects allow designers to modify their geometrical and non geometrical attributes. The adaptable design objects are not intelligent agents but rather intelligent objects. The intelligence of these objects is manifested in their capability to respond to agent's queries and follow agent's instructions. The intelligent abject are equipped with certain operations that allow them to move, rotate, cut, and scale when they are instructed by the situated action agent.

The design semantic support tier focuses on providing semantic support to human designers during the design process. The semantic support is primarily spatial and esthetical. Spatial semantics include segregation, interconnections and adjacency. Esthetical semantics include expression, symmetry and modality. The semantic support is provided by the situated action agent. The multi agent system is comprised of agents at three levels: Observation-Sensation-Perception, Conception and Action as shown in Figure 2.

Within the proposed framework, the Observer agent tracks designer's actions and their sequences including selecting and locating design objects and moving or deleting objects. The Sensor agent detects design objects whenever they are placed or modified in the virtual environment. The Preceptor agent builds its interpretation of the current design in the virtual environment through what has been sensed and observed. The Conceptor agent is an incremental learning agent that has pre-coded descriptions of spatial and esthetical semantics. The relationships between design semantics are not pre-coded but

rather learned by the Conceptor agent. It learns from observing the interaction between the designer and the virtual environment and other agents including the Situated Action agent.

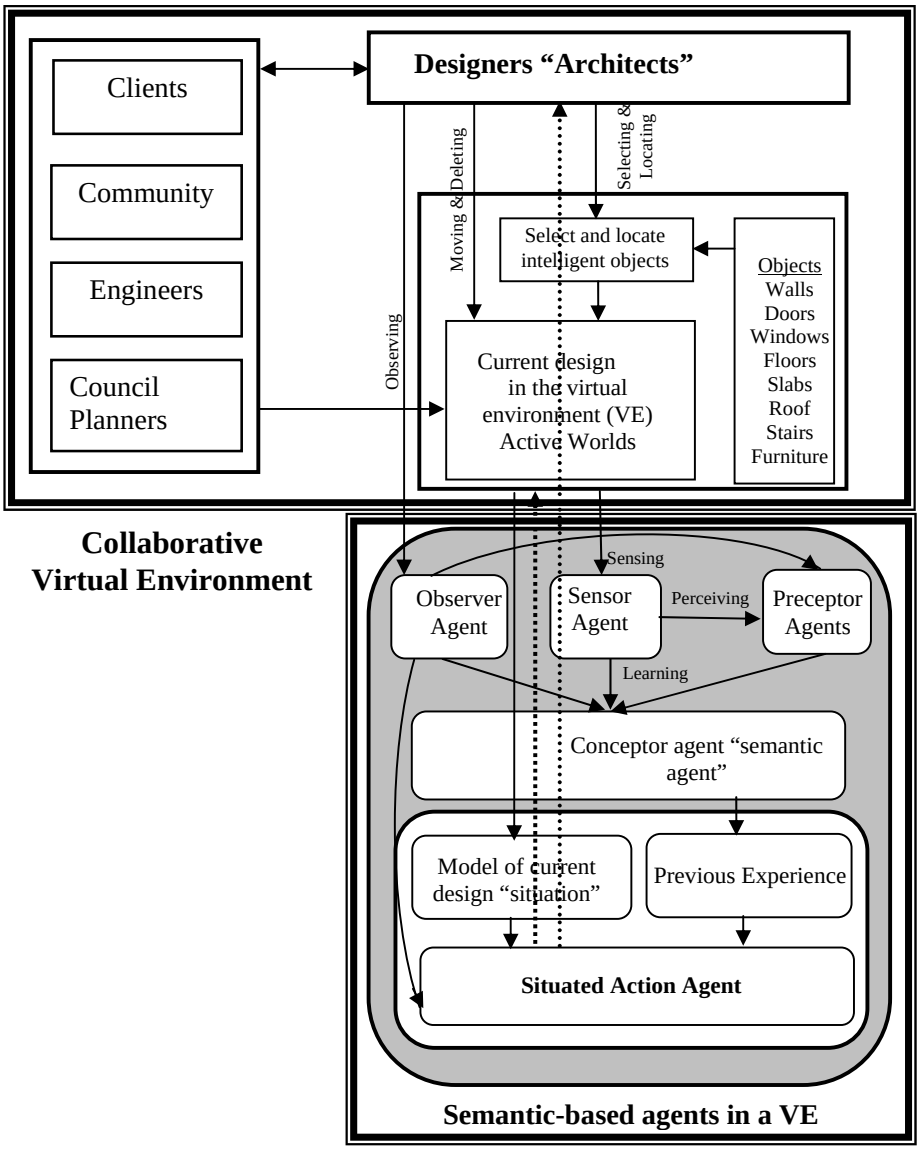

Figure 2. Proposed framework of an intelligent and collaborative design environment.

The Situated Action agent decides its course of actions in response to designer's actions based on its previous experience and its internal model of the current design in the virtual environment. These actions are manifested either in changing the current design in the virtual environment or advising the designer in relation to a specific design semantic in

his/her current design The proposed Situated Action agent does not follow a series of rules in response to pre-programmed set of design values but rather these values are learned by the agent in relation to specific and encountered situations. What separates it from the many similar agents that have been developed in recent years are its situatedness supported by its learning capability, its capability to modify its previous experiences in an incremental learning fashion and its situated capability to decide the best set of actions to be invoked in future situations.

The social dimension is provided by offering a conduit between multiple human opinions and information sources to offer instructive, constructive design suggestions. This is reflected in the interactions within the VDE between the designers, clients, community and planners. VDEs provide an online multi-user opportunity for discourse and commentary between parties, providing both the conduit for communication and discussion and an environment in which 3D visualisation can assist the process. Typically, comprehension of design plans and associated technical details requires expertise particular to designers. A visualisation technique, as formed by the models in a VDE, presents a universal representation of information relevant to various parties involved – designers, clients, community, engineers and council planners.

Appending comments, altering or experimenting with configuration of models and appearances, discussion via chat and posting opinion on whiteboards/bulletins/signs are some examples of ways in which the VDE can accommodate the diverse interests and focus interaction between social groups. The multi-user attribute of a VDE is critical to synchronous discourse between multiple human opinions and information sources. The diversity of presentation methods, that can include web pages, chat forums, postings, images, plans, models and an immersive walk-through impression assist in bringing together instructive, constructive design suggestions. The intelligent design agents will vastly enrich the interaction and process of offering design suggestions. This VDE ensures access to shared knowledge concurrently with the forum for collective input and discovery.

Visualisation is of assistance particularly to non-designers, non-experts as a methodology for understanding discipline-specific design representation techniques and jargon. Visualisation demystifies the outcome, breaking down barriers for discussion between diverse interested parties. The constructive nature of the VDE can allow different participants to contribute collaboratively, collectively or experimentally towards a design, for example scope might include movable/interchangeable objects for clients and community to experiment with or poll on.

5. Conclusion

The integration of social and technical process using intelligent agents and collaborative design environments has great potentials to support designers at the early stages of designing and transform the use of CAAD in designing the built environment. The proposed framework of a multi agent system within virtual environments provides a platform for such integration. The interaction between actors of the design process including architects, engineers, clients, council planners and community and interaction between designers and agents are essential to provide useful transformation to the use of CAAD in the design process . Agents have different levels of interactions with the environment and the designer. These levels range from tracking designer's actions to introducing changes in the environment or advising designers of certain design semantics. The agent's capability to learn the relationships between design semantics and build its own design experience allows the agent to perform and act in future situations. The agent takes the best course of actions in future situations based on its previous knowledge aligned with the current situation in the environment. VDEs provide an online multi-user opportunity for discourse and commentary between parties, providing both the conduit for communication and discussion and an environment in which 3D visualization can assist the process.

The potential benefits of developing intelligent and collaborative virtual design environment include improving the design support and collaboration at the early stage of architectural design. If Users and agents will collaborate, designing using computers will become more humanly rather than more automatic.

6. References

Beckmann, J.: 1998, *The Virtual Dimension: Architecture, Representation and Crash Culture*, Princeton Architectural Press, New York.

Brereton, M.,. Cannon, D., Mabogunje, A. and Leifer, L.: 1996, Collaboration in Design Teams: Mediating Design Progress through Social Interaction, *Working Paper*, Center for Design Research, Stanford University, Stanford, CA.

Churchill, E., Snowdon, D. and Murno, A.: 2001, *Collaborative Virtual Environments: Digital Places and Spaces for Interaction*, Springer, London.

Maes, P.: 1997, Agents that reduce work and information overload, In Jeffrey M. Bradshaw, J. (ed.), *Software Agents*, AAAI Press/MIT Press, pp. 145-164.

Maher, M.L., Simoff, S. and Cicognani, A.: 1999, Understanding Virtual Design Studios, Springer, London.

Mitchell, W. J. 1990: Introduction: A new agenda for computer aided design in the electronic design studio, *in* Mitchell, B. and McCollough, (Eds.), *The Electronic Design Studio*, MIT Press, Cambridge, Mass.

Moran, S., Card, S. and Newell, A.: 1983, *The Psychology of Human-Computer Interaction*, Lawrence Erlbaum Associates, Hillsdale, N.J.

Nass, C., Steuer, J. and Tauber, E.: 1994, Computers are social actors, in *Proceedings of the International CHI Conference*, Amsterdam, Netherlands.

Norman, D.: 1994, How might people interact with agents. *Communicatons of the ACM*, 37, pp. 68 - 71

Pu, P. and Lalanne, D.: 1996, Human and Machine Collaboration in Creative Design, European Conference on Artificial Intelligence, pp. 276-282.

R. Aylett and M. Luck, Applying artificial intelligence to virtual reality: intelligent virtual environments, Applied Artificial Intelligence, Vol. 14 (1), 2000, pp. 3-32.

Turk, Z: 2001, The Reasons for the Reality Gap in CAAD, Proceedings of the 19th Conference on Education in Computer Aided Architectural Design in Europe, Helsinki University of Technology, pp. 156-160.