The Changing Face of Architectural Computing Research

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This paper examines the existing commercial and on-going research computer applications for architectural design. It investigates their uses, predictions and limitations; and reviews the teleology, technologies and theories exploited for computerising design. Finally, I will discuss two trends in the developments of CAAD, and present the new directions in CAAD research. This study will be based on understanding the computer's roles in designing, and further on establishing a new theoretical paradigm for mediating a computer system.

Keywords*: historical context, theoretical paradigms.*

The Emergence of CAAD

The ultimate purpose of design studies is to provide the designer with more efficient ways to be able to deliver better designs more quickly. One of the most important events in design studies since Design Methodology Movement, was the emergence of computer-supported designing in the simple form of software that executes parts of design processes.

In the 1960s, computer-aided architectural design (CAAD) studies appeared through experiments and research holding with the strong belief in the possibilities of an automated design process, by combining systematic design methods with computer technology. Many advanced fields, such as new mathematics, statistics or computer science, had much influence on the earlier computation of design, but its roots lied in the systematic design methods, which had provided the foundation of knowledge on which CAAD research could build. Thus, the pioneers of CAAD programs began with facilitating the existing established methods into computer programs (Harfmann, 1987)

Naturally, the first successful use of computers was mathematical models, where large amounts of numbers and equations were easily managed. Examples include cost control, structural calculation, simple space allocation and circulation in building. The development of mathematical models and systematic design methods seemed to be the preparatory steps for computerising the design activities.

Actually, many scientific design methods were transferred to computer models; such as space need analysis, interaction and grouping analysis, spatial synthesis, and cost and environmental analysis models. These models dealt with mainly design analyses and evaluations in design activities, which could be implemented by algorithmic programming.

Later, the development of AI and cognitive science has led many CAAD researchers to focus on the computation of the design process. Their efforts may be the prerequisite steps for the entire design processes to be executed automatically, or at least efficiently, within a computational environment.

Parallelled with the enthusiasms to automate the design process, applying computers as a graphic tool to architectural design began with Ivan Sutherland's pioneering work in the 1960's. Further important works started in the early 1970s with the advent of the storage tube graphic display from Tektronix, and was boosted by the arrival of effective minicomputers such as the PDP-11 and the Prime 300 (Richens, 1991). Ever since computing power became commercialised and computers have been extensively employed in the design practice, many researchers have worked on programming the design process into intelligent systems, or applying advanced computer technologies to designing. Consequently, a number of papers on computer-aided design have emerged in design conferences and publications and CAAD became a major subject in its own right (Mitchell, 1977). It seems that the enthusiasm for design methodology has become convergent with computer-based methods.

As a result, CAAD researchers have been concerned not only with the technological advances of computer science such as computer programming, database systems, and computer languages, but also with its theoretical framework that can accommodate designing with computer. That is, they required the more sophisticated theories than the earlier systematic design approaches. For this, many design studies - especially CAAD - have taken up their theoretical framework from information theories such as 'design as information processing' or 'design as a problem-solving process', which is amenable to computerising design.

The Two Trends in the developments of CAAD

If we look back at the nature of the research undertaken in architectural computing over the past four decades it is possible to identify two obviously different ontologies of computers for architectural design. The shifts in the CAAD research focus over the past 40 years can be described as follows.

Two Different Directions in CAAD

Since CAD was introduced in design studies, many design activities have been computed, such as problem analyses, drafting, visual representations or even certain solution generating algorithms. There are two obvious tendencies observed in CAAD research: (1) viewing computers as a thinking machine and (2) viewing computers as a design tools. While the first direction has tried to solve design problems by representing design knowledge, rules or principles in computers, the second direction has aimed to help designer to draw faster, or produce photo-realistic renderings and animation in real time. The characteristics of two directions are distinguished in the following table.

As shown table 1, the first category – the computer as an intelligent system - regards computer as a thinking machine that has some structured knowledge to solve design problems and thus its theoretical framework is borrowed from information-theories, in which design is interpreted as a problem-solving, a decision-making or a knowledge-depended activity. It emphasises design knowledge, information and the designer's cognitive process, so that its characteristic is academic, experimental and future-oriented. As discussed in the previous section, despite of the development of technologies in computing and AI, this field has not developed for the design discipline as much as had been anticipated.

The second category has focused on design supporting tools such as drafting, modelling or representing environments. Their aims, whether to be commercial or not, lie in improving the usability of computer for design and the efficiency of design; that is, in developing a friendly, usable application by employing state-of-the-art techniques of computer science. In addition, the developments in design presentation technologies now led by the commercial CAD companies, such as three-dimensional modelling, simulation or virtual reality, will inevitably be continued.

Changes in the CAAD Research Focus

Since design methodologists started dealing with the computation of design in 1960s. Researchers from both sides – computer as intelligent system and computer as design tool - have evolved their technologies and theories for CAAD. It can be observed that the main stream of CAAD research has

Table 1 (right). Two different directions in CAAD: Computer as an Intelligent system and computer as a Design tool

	Intelligent System	Design Tool
Computer	As a thinking machine	As a design tool
Concept	Computability of design	Usability of computer
Ideology	Rationalism	Pragmatism
Related fields	Artificial Intelligence	Computer Science
Feature	Academic, Theoretical	Commercial, Practical
Design Systems	Knowledge-based systems, Expert systems, Case-based systems	CAD drafting or modelling programs, Information-management systems

shifted back and forth between above two directions over the past 40 years. Here, I identify four periods broadly by decade. Of course, this observation does not indicate the developments of computing generally, but is limited to the shifts between the two different views of CAAD research.

- **First period** (the 1960s): The architectural system of the 1960s introduced as a means to facilitate the existing established design methods, with the goal of automated design systems. Thus, the role as drafting or visualising tool was not paid much attention due to the capability of software and hardware.
- **Second period** (the 1970s): By the 1970s, a number of ambitious software design projects were commissioned by the public sector and useful work for architectural design started - including planning, evaluation of alternatives, cost planning or structural design. This was also the era when the naiveté of the approaches to automation become obvious (Richens, 1992). At the same time, simple drafting systems became developed and were taken a growing interest in by CAAD research.
- **Third period** (the 1980s): During the 1980s, the hardware improvements and the notable development of commercial CAD applications led PC-based architectural offices to become widespread. As the computer as drafting systems succeeded, in turn, the academic interest dwindled (Richens, 1994) and interest moved towards more philosophical problems.

Along with the awareness that logic and algorithms alone could not solve the related design problems, CAD researchers started to draw new clues from advanced technique in AI. In this period when some expert systems were successfully implemented in specific fields, many intelligent design systems were suggested and experimented with by enthusiastic academic researchers.

- **The forth period** (the 1990s): CAD software industry continue to flourish during the 1990s, and thus many notable drawing and representing tools appeared in increasingly sophisticated form and at shorter intervals. Meanwhile, compared to the remarkable commercial success of graphic design applications, intelligent design systems have

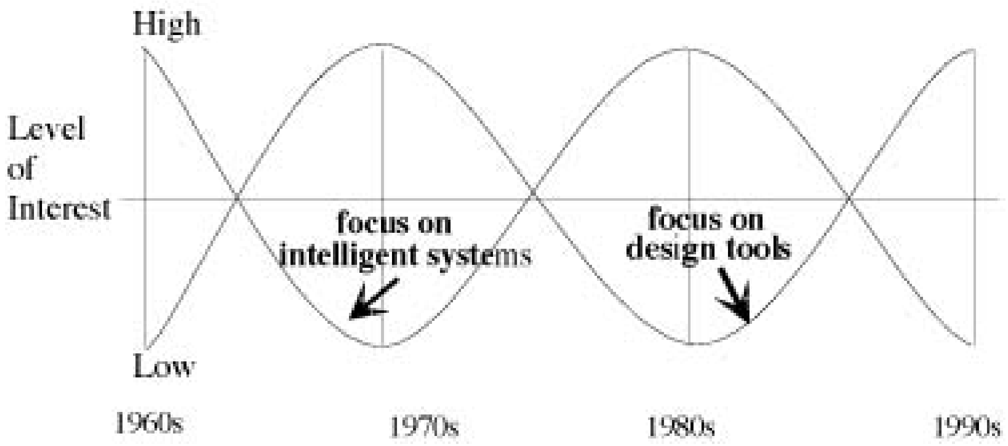

Figure 1 (left). Shifts in the CAAD research focus over the past 40 years

> proven to be a much more difficult and elusive undertaking than anticipated (Pohl and Myers). In addition, the disappointment in the result of 'The Fifth Generation Computer Systems (FGCS)' project (Ueda, 1993) led to a decline in interest in the brief on the feasibility of AI in design.

In sum, the view of computer as a design tool has been given varying degrees of attention by researchers, but the applications have been continuously improved in form of advanced graphic technologies. Along with the commercial success of CAD software, the steady increase in power and the reduction in cost of computer hardware have made commercial CAD systems more popular in design practice and this in turn has had a significant effect on architectural design practice.

Meanwhile, despite the development of AI technique and computer languages, intelligent systems for the design domains, especially for architectural design, have evolved very little, compared to the other fields and the expectation of the earlier CAD researchers. Even though, using the relatively new technology in AI such as neural networks, case-based reasoning and fuzzy reasoning, most of them fail to generate reasoning systems up to a significant level to offer a plausible solution to real design problems.

Gero (1987) predicted, in a paper presented in CAAD Future '87, that intelligent systems would be the core tools in computer-aided design with their ability to automate reasoning through automating inference processes (Gero, 1987). However, after 10 years, he (1997) acknowledges the difficulty of applying computer reasoning in the design domain, and that there are still very few well-developed intelligent design support systems in use today [A]. The decrease in the number of papers on the subject in CAAD conferences demonstrates the recent change of the concern of CAAD research. That is, it is a conspicuous phenomenon in CAAD research to shift their interests from the automating or reasoning of design to the more sophisticated design tools by applying the state-of-the-art computer technology to the design domain.

Conclusion: New Approaches to CAAD

In conclusion, there is so far no design system that can give complete support to all architectural design activities. That is, although some small parts of the design processes are implemented on computers, the system for a real design remains still being developed in both CAD software companies and the academic research.

The difficulties in building a design computational environment result from the combination of many obstacles: the lack of technology; the limitations of computability of design; the incompatible nature between designing and the computer, and so on. In order to overcome these obstacles, CAAD researchers have continued to suggest approaches to new design computational environments by responding to the capabilities of current computational technologies, or more philosophically, by proposing theories of evolution.

Man-Machine Symbiosis Environment

As an alternative to the failure of automated design as a whole, this approach – man-machine symbiosis computational environment - delimits proper roles for the human designer and the machine. That is, it combines human and computer capabilities for design in a complementary, integrated manner. Some notable examples include the *partnership paradigm (Swerdlof and Kalay, 1987), computational design support environments (Coyne and Surbahmanian, 1993), Knowledge-Based Design Support System (Oxman and Oxman).*

Mitchell (1994) suggests a more practical approach: "to divide up the labour of designing in such a way that the human designer gets the ill-defined hard parts but the machine reduces the grunt work by dealing automatically and efficiently with well-defined easy parts". This may be a realistic statement in complementing the limitations of the existent CAD environments. Furthermore, it becomes a feasible assumption that computational systems can play the most effective role in enhancing creativity within human-machine design systems where the division of labour between the two participants supports exploration of problem formulations and solution spaces (Carrara and Kalay, 1994).

Though the symbiosis between man and machine appears to be possible theoretically, it is by no means easy to define which functions are allocated to human or machines on the basis of man-machine capabilities. That is, as Coyne and Subrahmanian (1993) pointed out, because we understand little of the design process and we lack a comprehensive model for integrating the abilities of man and machine into a complete design process. Based on these reasons, some research has focused more on the design of the user interface that can provide architects with the friendly and suitable design environment rather than the design of functional allocation in man-computer system.

Integrated Systems

Most applications for design have been developed from a particular theoretical, technical background with different functionalities; and hence each plays a partial role in the design process. Such single-purpose applications can not meet all of the designer's demands. Accordingly, the demands of the integrated system reaches right back to the start of CAD in the 1960, with an assumption that computers would be used to store and operate on information for all design processes (Bijl, 1989) However, such ambitious systems that integrate all phases of the design life-cycle still remain unrealised.

Recently, the development of AI in design has led to the embedding of AI-based applications into traditional programming; that is, combining CAD programs with relatively new technologies from logic programming and knowledge-based systems of AI. For these systems, design objects have a specific behaviour as well as its own property, for example a column knows that it must locate itself between beams or slabs and so on (Richens, 1992) Each piece of intelligent behaviour can be formalised as a rule that is employed in creating and displaying objects and geometry. In addition, such systems also offer design advice and standards across the domain disciplines (Reinschmidt and Finn, 1994).

However, these attempts to apply CAD program to the real design problem have been restricted to sub-problems that can be quantified, such as staircase construction, welding, lighting, and thermal analysis (Pohl and Myers). The basic difficulties in integrating reasoning systems with CAD programs lie in the incongruous functionalities between them. That is, each application is designed for a completely different environment and each has completely different functionality or reasoning system - the logical or symbolic reasoning and the geometric reasoning needed to create or to analyse geometric models.

A Design Medium for Communication and Collaboration

Recognising the difficulties of developing the generic design tools, CAAD researchers have attempted to gain new ideas from the state-the-art computational technologies or the advanced commercial software. One of the most significant issues is the interest of the appropriate design media for supporting the design collaboration. Bijl (1992) has already argued that computers do not think, but are better regarded as a medium of communication (Bijl, 1992). In fact, the development of telecommunication has already led the designer to use the computer as a medium for communication and collaboration, such as electronic mail, voice mail, whiteboarding or video-conferencing.

This new information architecture creates new communication activities and new information flows among participants in the design process. At the same time, CAAD researchers have investigated the potentials of web-based design interaction, multi-user workspaces, or shared virtual reality on a web site. These techniques can be useful to facilitate the various participants' information in design process, by storing, retrieving, sharing, adding, modifying and managing documents and drawings.

New Theoretical Models

The new approaches above have focused on developing more powerful design tools or more sophisticated data representations by exploiting advanced computer techniques; or on concocting new design computational environments like an integrated design system embodying a man-machine design environment. Meanwhile, another research strand has attempted to establish a new theoretical framework on how computers can be used for designing.

Pohl and Myers (1994) argue that the difficulties in building design systems are related not only to the ill-defined nature of the design activity, but also to the inadequacies of the representational and operational models that have been used as the framework for computation. In other words, most problems basically originate from the ignorance or misunderstanding about design itself and the misleading theoretical paradigm for computation, namely, design as problem-solving process. Thus, Gero (1997) acknowledges this fact like this: "We know little about designing: the activity carried out by designers" [A].

The suggestion arising out of this study is that a theoretical computational paradigm that can explain the designer's real process and can be based on computerising the design model needs further investigation. Accordingly, in Lee (1999) the limitations of the prevailing design computational paradigm in the architectural design domain are investigated , and a new design model is proposed; a Mental Space model.

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Lee, H.R. (1999) A Mental Space Model, PhD thesis, School of Architecture, University of Liverpool, 1999.

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