From Number Cruncher to Digital Being: The changing role of computer in CAAD

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The paper reflects on a thirteen-year period of CAAD research and development by a small group of researchers and practitioners. Starting with simple algorithmic drafting programmes, the work transcended to expert systems and distributed artificial intelligence, using computers as tools. The research cycle is about to begin afresh; computers in the next century shall not be detached entities but the extensions of man. The computer shall be the medium that will enable a designer to be what he/she really is. This future has already begun.

Keywords: *history of CAAD, CAAD design paradigms, CAAD future*

Introduction

Architectural profession is still searching for its own attitude toward the use of computers in design. So far, three computer science disciplines with seemingly similar design process and domain interest, have been "adopted" to establish the main paradigms for computer-aided architectural design (CAAD) research and practice. Traditional design requires making a lot of 2D drawing and 3D models to represent the intended artifact. For that reason, a part of the research community accepted computer graphics as the most obvious basis of the "Computer-Aided" design process that includes, paraphrasing Horst Rittel, the "First Generation of CAAD". Assuming that the design is the intelligent human activity, other researchers saw Artificial Intelligence as the main support for the proper model of design process of the "Second CAAD Generation". Recently, the advent of computer networking and the Internet made researchers recall that the contemporary design requires teamwork, thus proclaiming the distributed design and the Network-Based Collaboration as the new CAAD paradigm. At this point a kind of computer-aided "Design Studio" was established. However, challenged by the end of the millenium, the researchers world over seems to be addressing again the ubiquitous questions What CAAD? Why? Some hypothetical answers could be already outlined today.

This paper illustrates some of the work at the IMS Building Research Institute in Belgrade in CAAD domain. It was supported by modest means and performed by a small group of researchers. It spans some thirteen years, and chronologically follows the described pattern of the research paradigm shift.

First Generation of CAAD Methods: "Design is drafting!"

Our initial objectives were to research and develop the suitable computer tools that could aid design and manufacture of GIMS, a prefabricated housing building system that was developed at our Institute and applied in Yugoslavia and many other countries. Some of the needed software was partially available on the market but we nevertheless decided to design and develop most of the needed software by ourselves. Good side of this rather risky approach was that we were all the time in command of our work, and could experiment and adapt the software to the design task and not vice versa.

Among the first programmes were the applications of 2D drafting and 3D modeling and rendering algorithms. The results were Little Modeler, a background solid modeling program that enables automatic creation of boundary representation solids, and the 3D Viewer, a program that produces self-shaded, hidden surface visualization of the object. The next task was to use the computer to generate variety of desired architectural objects. We developed several exhaustive generators. The Layout Designer uses pattern-directed algorithms to produce all possible building layouts. The program consists of a set of predefined geometrical patterns describing layout elements, and set of rules for their mutual composition. The Roof Designer uses a similar mechanism to generate all alternative roofs on the top of the layouts generated with the Layout Designer program. The output of these programs can be sent to Little Modeler to produce 3D models of the buildings. All programs were implemented on the Micro VAX computer with HP color graphical terminal during in 1986.

Second Generation of CAAD Methods: "Design is thinking"

It soon became obvious that we needed evaluating and reasoning tools, so we switched our interest to AI mechanisms. The result was GIMS-Expert, a system that was really the "translation" of the existing GIMS Method (Petrovic et al. 1987). Its task was to generate, select and rank the satisficing solutions that comply with the design brief and are made of design/structural elements contained in GIMS Catalogues and assembled in accordance to the pre-set rules. We integrated all above-mentioned programs in a centralised, interactive system composed of tightly related modules. The most important modules were the Layout Generator, a problem specific monotonic-reasoning expert system shell that implements forward chaining deductive inference mechanisms evaluating and ranking the satisficing solutions, and the 2D and 3D representers.

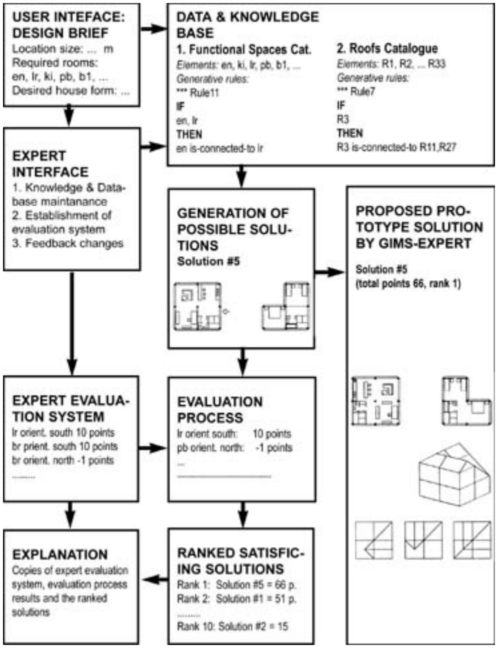
The starting idea of the programme was that all GIMS houses have two stories and are contained within the design space made of 3 x 3 horisontal planning /structural modules of 4.2 x 4.2 metres. The fixed, linear design sequence starts with the ground and first floor layout generation, continues by matching of layouts, evaluation and ranking of satisficing solution, to finally produces the 3D representation. Written in LISP code, the programme offered explanation of all design decisions. In 1986, the initial implementation platform was Micro VAX computer, while in 1991 the programme was adapted to PC. GIMS-Expert was greeted with silence by the colleagues and treated as a possible threat to their jobs in certain projects field. When this possibility came near to reality, we stopped the development of this programme.

In the 1988 it looked that personal computers will be the future of the application of computers in architecture. For that reason we began to re-implement our previously developed programs for the PC computers because of the application of the existing commercial drafting programme. In addition, we also implemented Arch, an exhaustive non-redundant multi-story layout synthesizer based on a depth-first branch-and-bound algorithm, and Oyster and Maria, problem independent monotonic-reasoning expert system shells that implement both forward and backward chaining deductive inference mechanisms. All programs run as the separate programs under the MS-DOS operating system. An interesting application of MARIA shell was the development of a programme containing the Belgrade Housing Code in 1991.

The Design Studio: "Design is communicating and cooperating!"

In the 1991, with the emergence of the new Intel processors and the MS Windows 3.0 we used multitasking and the Dynamic Data Exchange (DDE) protocol to develop a distributed system leaned on the on-going research in Distributed Artificial

Figure 1 (right). Architecture of GIMS-Expert



Intelligence. This was the chance to remodel GIMS-Expert in the light of the new possibilities. The resulting DDS system (Svetel 1994) is modeled as an “open society” of autonomous, cooperative, heterogeneous design agents. Each agent represents a particular design tool that enables transformation of the evolving design from one state to another or the representation of selected parts of the information that describes the current design state. Each DDS agent is capable of solving part of the design problem from a particular point of view. To establish a global solution each agent has an ability to communicate its results to other agents in the system. A knowledge base that supports the process and a data model that describes the evolving design are both distributed, enabling simultaneous modeling of different design spaces, and broad representation of design variety. The system is organized as a heterarhical society without any predefined points of global control. The system supports ‘whirling’ succession of design actions without predefined sequence of steps, beginning or closure of activities. In the first implementation the system organization and knowledge base content supported the distributed problem solving view of the design process. GIMS-DDS was partially applied in preparation of design and realisation offer for building housing settlements containing 2000 individual houses intended to be sold on the open market (Petrovic 1998).

With the inauguration of the computer network at the IMS Institute in 1994 and the propagation of the Intranet we broadened the distributed nature of the DDS system to include distribution of the design task among many designers connected with the computer network. Thus a shape of a possible new type of Design Studio had begun to emerge. It featured the Cooperation Manager programme (Svetel 1995), based on the research on the beginnings of collaboration among children, identifying four cooperative formats (Verba 1994). The *observation-elaboration* cooperation format enables the designer to access the design resources of the another designer. The designer can examine the content of the resource, apply it to his/her design process, or use it as an instance for the development of the new resource. The *co-construction* cooperation format enables the designer to apply his/her resources in projects of the other designers, or to modify their resources. The Cooperation Manager takes care of revisions and offers to the designer three options to deal with them: accept, reject, and modify. The *guided activity* format enables the designer to use the design method of another designer, or to explicitly ask for help from another designer. Since all information in the DDS system is open to other designers, and designers using the system implicitly propose their designs to all designers, the *transmission-appropriation* cooperation format is not considered in the implementation of the programme. The programme supports asynchronous collaborative design activity among a group of designers working on the local area network. The cooperation is modeled

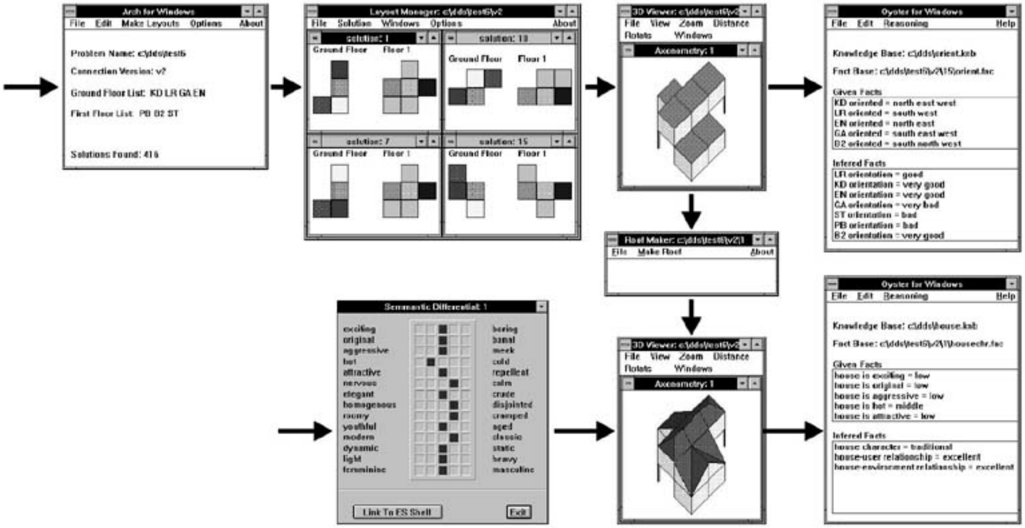


Figure 2 (left). GIMS-DDS

as a peer-to-peer interaction among pairs of designers.

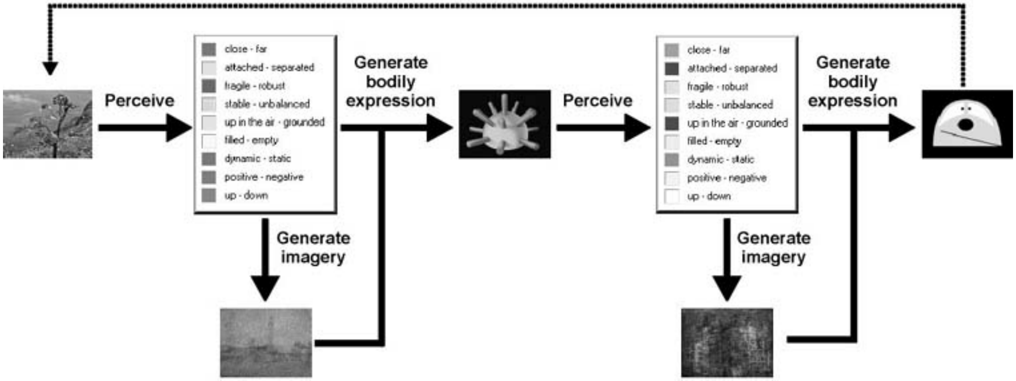
Some Experiments

Our experiments with the subjective side of computer-aided design began in 1990 at the Industrial Design School in Belgrade. It started with a prototype of the programme ThinkDraw that associated the design of a "modular car" with the semantic differential, meaning the association of a picture with the word. The car assembly consisted of elements that were placed in a knowledge base and associated with the particular outcome of the semantic differential via a simple rule-based inferring mechanism. One could "design" a particular car expressing his/her desires. Unfortunately, beyond the development of the first prototype, this experiment was soon terminated (Petrovic 1990).

Much more sophisticated and complete result was achieved by PDP-AAM programme that associated picture and word via a neural net (Svetel 1991). The programme is composed of three layers, first, a 3D editor of GIMS houses, the second, the neural net, and the third, a semantic differential. The inner, invisible layer represented the knowledge, attitudes and preferences of a person that was learned by the neural net. The first and the third layer were the input-output mechanisms allowing two essential design activities: a) assessment of a GIMS building by the applied learned neural net reflecting someone's attitudes, and b) proposing a GIMS building that reflects the desired characteristics expressed in the semantic differential. The most interesting feature of this programme is that it would "create" a new building composition that was not contained in the examples that the neural net learned. Thus, new variables appeared in the process. PDP-AAM proved to be an interesting companion of the "logical" shape-generating programmes and a good demonstrator of neural net principles at school (Kalay, 1998).

The follower of PDP-AAM was the "VVA" pogramme. The programme roughly simulates architecture of human visual system. It uses feedforward backpropagation artificial neural network to associate visual and verbal representations. The visual representation and 'iconic visual memory' are implemented as bitmap pictures, while the verbal

Figure 3 (right). Semantic communication between robots using VVA



representation is implemented as a set of strings associated with specific neurodes. The program uses two networks to realize associations. The first network associates a bitmap picture with a set of strings simulating feedforward pass of signals from the ‘perceptual’ layer (retina) to the ‘verbal’ layer containing associated categories. The second network associates a ‘verbal’ layer with a second bitmap picture that plays a role of ‘iconic visual memory.’ Thus, presenting a picture the program can activate associated verbal categories, and can recall a ‘mental image’ associated with categories. A ‘mental image’ can be activated without the ‘perceptual’ input by directly activating categories in the ‘verbal’ layer. The program supports simple recurrence by spreading activation from the ‘iconic visual memory’ layer back to the first hidden layer behind the ‘perceptual’ layer. The ‘mental image’ can activate categories in the ‘verbal’ layer using two channels. The signal from the ‘iconic visual memory’ layer can activate verbal categories using the same channels as ‘perceptual’ signal. The second channel uses recurrent connection and mixes the signal from the ‘iconic visual memory’ with the signal from the ‘perceptual’ layer, simulating the influence of expectations on the ‘perception.’

Finally, the authors are conducting some experiments that are not strictly in the realm of architecture and building. At the Industrial Design School of the Faculty of Applied Arts in Belgrade, students are engaged in designing the dynamic form and behaviour of autonomous robots, “possible human companions in future”. This field is enjoying a great deal of attention via research and development on autonomous agents (Pattie Maes at MIT MediaLab), “emotionally intelligent agents” (Clark Eliot at St.Pauls U.), etc. Our efforts address only a small fraction of this domain being related to “4-D design” (Robertson 1995). Our interest was in how people react to the various anthropomorphic and non-anthropomorphic forms of robots, and recently, how these machines could communicate among themselves the visual way, “feeling” and “sensing” the visual messages. The present idea is to apply AAV programme to robots to enable them to “percept” the message that is communicated visually, and act accordingly in tune with their attitudes impressed in the neural net (http://www.fpud/bg/ac/yu/id/4ddesign.html).

A Perspective

To be sure, in the next century the increasing housing needs in the world shall press for automatic designers, and similar well-defined programmes, including visualisation. But this is already the past of CAAD. We believe that the CAAD future can be sensed already in the on-going design research and development all over the world, on one side, and the new ideas in science and technology on the other. Our experiments with the communication among agents, and later among people, is quite relevant to the repeatedly asked question about the role of computer in design process.

Traditional views see the computer and the designer as detached entities. The computer is seen either as a tool, assistant, autonomous agent etc. Influenced by work of the hermeneutic philosophers, and the recent findings in cognitive science and neuroscience, we have adopted the view that the computer is an indispensable part of the design process, and that the designer and the computer represent coupled cognitive system. Actions that designers make are not used to reduce difference between the current and goal states, or to implement a reaction to the environmental stimuli. Instead, people use these actions to change the environment in order to achieve the better understanding. These actions, termed *epistemic actions*, improve cognition by reducing amount of internal mental information processing (Kirsh and Maglio 1994). The epistemic action performance relies on the external artifacts that enable understanding by augmenting current situation with new representation. It can be conjectured that the mind has evolved in a way that directly relies on the existence of manipulable external environment. Thinking, according to this view, shares the same process structure as perception, and has gradually evolved through social interaction and participation in a culture (Burke 1995). Instead of dealing with the whole world, as perception does, thinking is oriented toward representations embodied in linguistic, discursive, or expressive media. The process has a cyclical structure. The person realizes his/her ideas in some representational medium. The application of formal processes (proof, derivation, calculation, etc.) on representations yields consequences of these proposals. The consequences are also expressed in some representation. These new representations trigger concepts in the mind generating new ideas that can be further expressed using some external structure.

The design is an explorative process during which a designer uses some representational medium to express and communicate his/her ideas about the intended change in the environment and about the artifact that realises that change (Petrovic 1977, Galle 1997). These expressions, being also artifacts, modify environment in a way that enables a designer to acquire better understanding of his/her idea. Namely, the design is the constructive exploration about what can exist, and how it can exist. The computer is seen as a medium in which representations are formed and communicated. The design process is modeled as a collaborative effort on three levels: among computer-based agents, between person and computer, and among human designers.

This approach differs from AI approach because the designer's interest is not to have intelligent assistant or some smart controller to peek over his/her shoulder watching him/her designing. All he/she wants is to express his/her idea from all conceivable aspects. He/she needs a medium to express himself/herself. Artefacts that the designer creates, the process he/she uses to create it, and the knowledge used, all represent the expressions of designer's personality. And the computer is the medium that should enable designer to be what he/she is.

References

T. Burke, Dance floor blues: The case for a social AI, Stanford Humanities Review 4 (1995)

P. Galle, P. "Design as intentional action", Design Studies 19 (1998)

D. Kirsh, P. Maglio, On Distinguishing Epistemic from Pragmatic Action, Cognitive Science 18 (1994) 513-549.

I. Petrovic, M. Novkovic, M. Cubric, I. Svetel, and Z. Minjevic, GIMS-Expert, International Conference IMS'87, Belgrade, 1987, 233-241

I. Petrovic, On problems and methods in design (Faculty of Architecture, University of Belgrade, Belgrade, 1977). (in Serbian)

I. Petrovic, On Some Issues of Development of Computer-Based Architectural Design Systems, in G. Carrara, and Y. Kalay, eds., Knowledge-Based Computer-Aided Architectural Design. (Elsevier, Amsterdam, 1994) 269-301

I. Petrovic, ThinkDraw, Design Research Society Symposium, London, 1990, 35-41

I. Svetel, DDS - Distributed Design System: A Paradigm for Modeling Conceptual Architectural Design, in: J. Pohl, ed., Advances in Computer-Based Design Systems, (The International Institute for Advanced Studies in Systems Research and Cybernetics, Baden-Baden 1994) 79-88.

I. Svetel, Human - Human Cooperation in the Distributed Design System Framework, in: J. Pohl, ed., Advances in Cooperative Computer Assisted Environmental Design Systems, (The International Institute for Advanced Studies in Systems Research and Cybernetics, Baden-Baden, 1995) 61-70.

M. Verba, The Beginnings of Collaboration in Peer Interaction, Human Development 37 (1994) 125-139.

Acknowledgements

This work has been supported by the Ministry of Science and Technology of Serbia and the IMS Institute grants. The project director is Ivan Petrovic.

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