CID - Computer Integrated Design : The context for future computer-aided building design

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ABSTRACT

Much research work has been done to develop stand-alone and integrated programs for use in various aspects of building design problems. This paper first identifies the difficulties that remain to be resolved to make computer systems truly useful in assisting design decision-making so that better and economic solutions can be achieved. Arising out of this, the paper outlines the specification for a new generation of software which will allow the integration of computers in the process of design, called CID - Computer Integrated Design. This will allow a designer to follow his or her own process and representation of design. CID will generate design information, and not just results of analyses like thermal, lighting, and cost, etc, very much needed in design development.

CID - Computer Integrated Design
Environement pour une future Conception Assistee par Ordinateur appliquee au batiment.

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MOT CLES:
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RESUME

Beaucoup de recherches ont ete orientees vers le developpement de programes independants et integres appliques aux problemes de conception dans le domaine du batiment. Cet article commence par identifier les difficultes qu'il reste a resoudre afin de rendre ces systemes vraiment performants en ce qui concerne l'aide a la decision dans le but de permettre d'achever des solutions meilleures et plus economiques. A partir de cette analyse, cet article degage les specifications d'un logiciel de nouvelle generation qui permettra l'integration de l'ordinateur dans le processus de conception. Ce logiciel, appele CID (Computer Integrated Design) permettra au concepteur de suivre sa propre methode de conception et de representation. CID fera plus que produire seulement des resultats d'analyse (evaluation thermique, economique, eclairage etc.) il generera l'information necessaire au processus de conception.

1. Introduction

Building design, construction and maintenance form an exceptionally rich scientific arena because it requires the application and integration of knowledge from the physical sciences, engineering, architecture, planning, economics, and the behavioural sciences to provide the architecture of the built-form. This knowledge domain, as can be imagined, is too wide for an individual human being to assimilate in detail and apply; and quite difficult even for a team of experts. Computers have been used to address parts of the problem in a fairly ad-hoc manner, but with the increasing sophistication and advances in computer technology, it seems likely that the computer systems of the future can assist in providing better solutions to this complex problem. This paper reviews developments in computer aided design (CAD) of buildings and suggests an approach for the type of systems that should be developed for the future.

2. Overview

An extensive repertoire of computer hardware and software already exists for a fairly wide cross section of applications. Many stand-alone systems have been developed mainly to carry out complicated or repetitive calculations. Some integrated systems have been tried in practice to evaluate design proposals. Comprehensive data-base facilities have been developed to store a building's geometry so as to allow automatic preparation of data for engineering analyses, cost checks, etc. Why is it then that the building profession is slow in taking up the full benefits of CAD? Are the tools of CAD not responsive to the needs of the profession? It has been recognised for some time that a mismatch exists between the practice of architecture and the structure and organisation of computer tools[1]. One of the main problems is that these systems operate very differently from the activities of the practioners. Secondly, the systems do not contain the information necessary to make design-decisions. Before developing a new generation of systems however, it is imperative that the needs of the profession are clearly identified. It is important to know how people design : how is a design perceived, how is it formalized using various forms of expression (representation), and how is the product achieved as a trade-off amongst many diverse requirements and from the many (almost innumerable) possible solutions. Before we redefine the role of computers in architecture and building therefore, let us attempt to identify the reasons for the mismatch between computer tools and practice.

2.1 The nature of design activity

Building design is not an algorithmic but a fluid holistic process. The end product is not achieved by a step-by-step process; instead all the major parts have to be manipulated at every stage in design development. Despite significant contributions made over the last twenty years, there is still no clear understanding of the nature of design activity. The design discipline has been described as informal and inconsistent, and the procedures in design, idiosyncratic, ill-defined integration of knowledge and experience[2]. It is not clear if there is a logic of design, but designing is inextricably bound up with evaluation[3]. For this reason computer tools for appraisal and evaluation of design have found a reasonable degree of success[4]. Though

most accept designing as a problem-solving process, this approach too has been questioned[5].

2.2 Representation of design

From inception to completion of a building project, the information generated grows like an inverted pyramid[6]. Extensive research has been carried out for adequate representation of this information in computer models[7]. There is also a plethora of information which the designers use in making design-decisions which has only been used in a very patchy fashion by computer models as climatic data. fire rating, etc, but not in an integrated way. Very large and complex computer systems will be needed to provide all the necessary information in an integrated data base[8], and, where this has been attempted experience has shown that such systems require arduous training for the users of the system[9, 10]. The large part of such data bases are taken up by object modelling, i.e. the representation of the shapes, topology and the attributes of various building components. A host of other relevant design information is not integrated into the system. Historic cost data on the capital and life-cycle costs; building codes and regulations for user needs and various engineering aspects; information on construction problems (availability of materials, labour, equipment, etc); information on maintenance problems (related to weathering, use, obscelescence, etc) are some examples. Clearly the representation of the geometric and topologic aspects of the built form have taken precedence. Methods of representation used and proposed are : set theoretic[11]; boolean description[12]; geometric modelling[13]; 3D modelling system[14]; and most recently logic modelling[15]. Each one of the systems tried in CAD practice have had varying degrees of success in representing the built-form. None of the systems provide a complete design information system. For example, geometric modelling has been useful in 2D drafting for production information, but the possibilities for use as a design tool have not been fully explored. Once again we find that CAD tools do not address the complete problem. We therefore face the challenge to understand and define our problems clearly so that the available computer technology can be gainfully deployed.

3. Computer models

It is recognised and accepted that a computer model is a good medium of representation, in the same way as drawings, and that a single computer model can comprehensively depict the information that normally requires many drawings, as well as pages of specification. The basic question is, how does a designer create a 3D model of a building? In the design of engineering artifacts, various parts which have a 3D size and shape, are plugged into each other based on the functional behaviour of each part. Hence CAD using 3D geometric modelling has been successful in engineering design. The building design process is quite different. Designing begins with a conceptual model of the whole and hence is not an overt process of fitting 3D parts together. Designing then becomes an activity of event exploration, in which partial responses lead to redefinition of the goal[16]. The conceptual model leads to the definition of a detailed 3D model[17]. The 3D model is generated after a long process of interaction, and is not necessarily a more sophisticated version of the initial conceptual model. This transformation relies on explicit knowledge plus intuitive judgement of the practitioners; a process that integrates knowledge and experience. An integrated CAD system should facilitate this medium of design; not just a medium of representation of an ensemble of 3D parts.

Computer models which have been developed for the representation of descriptive information, geometric and non-geometric relate to the syntax of design (Figure 1). They do not contain any semantics of that information which is essential to guide the designer through the evolution of the design. Designing is a learning process for the designer in which he finds an expression of his thoughts, by manipulating external representations of such thoughts. An integrated design information system should include models which represent the state of design at any stage in the process not merely as geometric description but also in terms of the fulfilment of a (partial) goal. Without design semantics CAD tools cannot provide a medium of design; they will merely replace paper and pencil by a computer screen and a light pen. The plethora of information is only transferred to computer memory. The designer needs assistance in utilizing all this information by relating various inter-related parts of the total design. This is all the more important when design coordination is necessary with a multi-disciplinary design team, for example the coordination of various building services[18].

3.1 Knowledge-based models

The aim of CAD therefore is not automation, indeed, some research is being done on automated planning systems[19]. Some functions like the production of drawings can be automated. It has been recognised that design products are inherently not predictable by overt procedures alone, nor by problem solving methods operating autonomously in a computer. The designer uses both overt knowledge and designer's intuitive knowledge as shown in Figure 1. This knowledge base has to meet the needs of the multi-disciplinary nature of design and must also adapt as design progresses through various stages of development. For the overt knowledge base, for example, the cost data base at the early design stages could provide approximate costing based on historic data on similar buildings, which would be quite different from cost data required for detailed estimating at a later stage. The overt knowledge base could provide automatic design checks on cost limits, building regulations, etc. It could even suggest possible solutions to the problem. Future CAD systems then, clearly, need design intelligence to extract necessary information from a knowledge base. It has already been argued that designing is not a step-by-step process where a different data base could be plugged-in to provide information about a different aspect of design, or at a subsequent step in the process. The design intelligence suggested here (perhaps in the form of expert systems) is not to automate production of complete design solutions, as this is an activity that requires designer's intuitive knowledge and creativity based on his or her heuristic learning and experience.

4. A new role for computers?

With the rapid advances in computer technology, building technology should be able to advance too. But since the impact of the computer tools developed over the last two decades is barely felt on the building industry, we

have arrived at a juncture when the role of computers may have to be redefined[20]. But before we attempt to redefine the role of computers, we should examine the current status in design practice and education. The large majority of the profession has failed to take advantage of the very basic benefits of computers even to allocate mundane, repetitive computational tasks to the computer to enable the designers to spend more effort on improving design solutions. Computers also have the capability to provide a large number of alternatives to choose from; so that the chances of an improved solution are significantly improved. Computer tools for design evaluation facilitate iterations of synthesis - appraisal, i.e. a test and improve cycle. In general, computer tools are predictive, dynamic, explicit and interactive. They help us to take a systematic and rational approach. This is not in contradiction to the intuitive and creative needs of design, nor to the need to develop a holistic design. In any design at some stage or stages, each part has to be separately analysed and evaluated for performance, which can best be done with the help of computers. This is what CAD has meant so far. But by and large the profession has chosen not to make too much use of this approach. Likewise, this important element is missing from building education programmes as well. If such tools were accepted and adopted, this could have provided the necessary rigour in design development. Is it because there is not enough pressure yet on the profession to produce built-environments which are responsive to the needs of the user and provide a good return on client's investment?

What then should our goals be, and what research efforts need to be expended to achieve these goals? Does the profession require integrated CAD tools with design intelligence and knowledge-based information systems? Would such intelligent CAD systems be acceptable to the profession? One of the dangers in using a computer tool is that the user may not question the validity of the results provided by the computer, and/or interpret the results wrongly. A computer tool should not be used as a black box. Knowledge-based systems may alleviate this problem with their ability to provide reasons for the solution provided by the computer. The danger of computer tools being used as a black box in an integrated CAD system would escalate unless there is also an integrated knowledge-base! Is it possible to create such a knowledge base?

4.1 Integrated models

It seems the issue now is that of integrated CAD which is currently taken to represent a computer system with a centralised data bank to store the general project information integrated with a centralised data bank to store general building (geometric) description. This is then used to service any number of application packages which can be attached to it to carry-out analyses on various aspects like thermal, lighting, cost, etc. It would indeed be very useful because separate data preparation is not required for each application area, and thus would greatly facilitate the use of computer aided design analysis and evaluation. It however, does not overcome the basic problems outlined above, viz the integration of the tools into the design process, and furthermore an analysis may be accepted without it being questioned. This also does not respond to the outstanding problem with computer tools in that they do not generate the necessary feedback which may be directly used by the designer to improve upon the design. The tools seem therefore only to automate aspects of engineering and cost analyses. The profession which has not accepted and/or used computer tools is unlikely to make use of these even if they were integrated in the fashion described above.

5. Computer integrated design

The specification for future computer tools seems quite clear. In defining them it is appropriate to declare a new concept viz, Computer Integrated Design (CID), whereby the design process and activities are integrated through the use of computers. This new generation of tools should have five important features :

(a) It should provide the designer with meaningful feedback which can be directly used to modify parts or the complete design. This further implies integration of analyses information and not just providing separate analyses of, for example, thermal, lighting or cost performances.

(b) It should have the facility for the specialist user to examine, question and if necessary, modify the algorithms and/or data used in an analysis.

(c) It should be able to answer questions from non-specialist users (clients, for example) relating perhaps to the context in which the design is being produced.

(d) It should allow for the idiosyncracies in each designer's use of the system and furthermore, allowing the designer to proceed at his own pace.

(e) Since the acquisition and integration of knowledge would of necessity, and by the nature of things take place over time, it should allow for the distilling and accumulation of knowledge over time.

To meet the requirements of the first feature, computer tools will need to generate not only the syntax of information but the semantics as well. Such information should gradually grow into a knowledge-base, as implied in point (e), through the interative process of design, which then will provide the necessary feedback to the designer as shown in Figure 1. Clearly the initial feedback, when the knowledge-base is small, will be minimal, but should grow into a snowball effect. Tools of knowledge engineering will be imperative to provide such feedback. Expert systems have been demonstrated to have the capability to meet the requirement of the second and third feature given that an appropriate overt knowledge-base can be generated. The fourth point implies the non-rigidity in the use of the system. It has implications for both the hardware and the software used to better match the way designers currently work.

As such computers integrated in design seems to be the answer to the effective use of computers across the spectrum of decision-making related to

the design, construction and maintenance of building. The concept of CID purports to fulfil the role of computers as design aids, which was the original goal of CAD tools. It goes further though. Rather than all embracing integration that seems now to be the goal of CAD, the implication of CID is the use of the computer as a sketch-pad, as a route-map, as a dictionary and when required as an encyclopaedia. It implies systems within systems and design spiralling out to its completion.

The concept given here is part of an on-going research on knowledge-based computer models. This will be illustrated fully with examples at the presentation during the congress.

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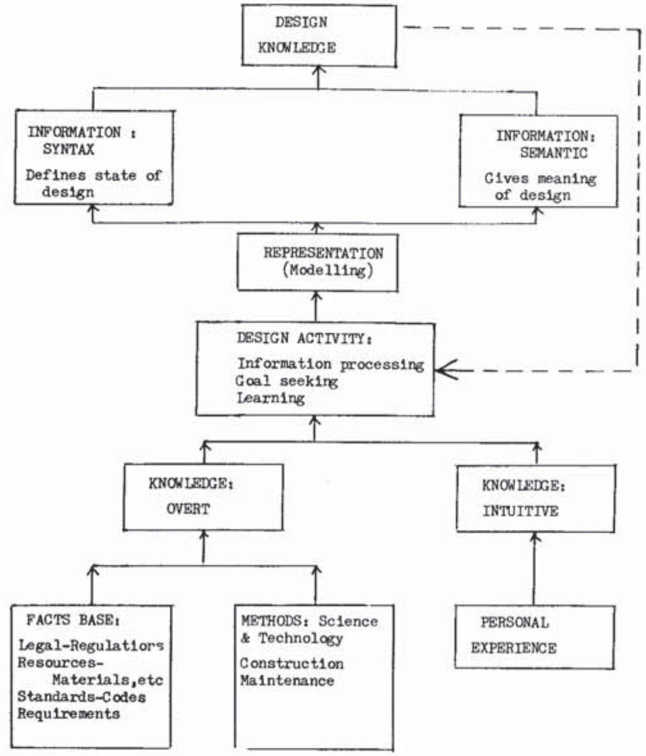

Figure 1