IT as Design Enabling Technology

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The purpose of this paper is to present a recent design offer for design and realisation of a sizable housing development. The computers were significantly involved in both, making the offer, and organisation of project design phase. The story illustrates some interesting relationships between IT and certain types of design problems. The paper presents how the offer was prepared, discuss whether the computers would be beneficial in getting the design tasks done, and finally, pose the question whether such design tasks could be achieved without the help of computers. The explicit design tasks and use of the computer tools make this case of «computerised craftsmenhip» appropriate for presentation in educational environments.

Introduction

If one states that information technology, and by this I understand all the computer hardwer and softwer philosophy and application in the widest sense, is the design process enabling technology, I presume this means that IT is claimed crucial in design procedures by providing the design tools and making design possible. But, how general is this statement? Does it mean that the architects should use computers in design without hesitation, knowing that without them the design work would be seriously impaired? Or that with computers, the resulting designs would be of the superiour quality?

If we were certain that the above statement was right all discussion about the role of computers in design would cease, and the new design paradigm would take place. The schools would know the importance of Computers in their curricula. The prospective architectural students would be selected not only for their ability of visual imagination and sense of space, but also for their ability to work with a machine as an assistant. What evidence do we have that such picture is a likely perspective?

Indirect supportive evidence comes from some specific fields of design. For example, design of a contemporary machine, be it an aeroplane, a car or a computer, would be unimagineable without computers. Today, no one would even dream of starting a technological design project involving the work of many thousands of people and costing billions of franks without the help of computers and the respective organisation of work. However, in architecture the picture is not so clear. Design and building of a hundred storey highrise would certainly be boosted up and be more reliable using the IT in all its fashions. And yet, the history of architecture makes us wonder how so many remarkable architectural achievements that exhibit enormous complexity were possible to build at all.

One of the opinions offered by architects is that computers are welcome and in fact compulsory in the organisation, preparation of drawings and other technical documentation, visualisation, and in calculation of various technical characteristics of a building. However, it is often pointed out that this is not so in the initial, preliminary design stages where the human spirit and creativity reign. Presently, the great efforts are being put into research of role of computers and creativity in design (Boden 1991, Gero et al 1993 etc.).

The purpose of this paper is to present a recent design offer for design and realisation of a sizable housing development. The computers were significantly involved in both, making the offer, and organisation of project design phase. The story illustrates some interesting relationships between IT and certain types of design problems. The paper presents how the offer was prepared, discuss whether the computers would be beneficial in getting the design tasks done, and finally, pose the question whether such design tasks could be achieved without the help of computers.

The Context: «Designing in a Building System»

To paraphrase the old saying, «there are all sorts of design offices that make the design world.» Our office specialised in design of "mass-housing" to be built in the GIMS industrialised building system (Petrovic 1982). The system is characterised by the reinforced concrete skeleton «structure» and various «infils» that complete a building (e.g. cladding panels, sanitary blocks, etc), similar to the ideas of Nicolas Habraken. Most of the system elements are stored in GIMS Catalogues, together with the rules that govern their interrelationships. Some people do not even consider the procedures of modelling houses under such circumstances as design, and consider them merely as "selections.» The task of these procedures is to select a proposal (a combination of elements according to rules) that has such characteristics that are nearest to the requirements given in the design brief. To prevent confusion, we shall make no difference between «selection» and «design» in further text.

Design with constraints of this type is by no means simple and easy. If the system elements and relationships had been designed without a creative touch (!), the selection is likely to be unsuccessful architecturally, regardles the efforts an architect may put into it. To avoid the monotony of appearance, one of the most frequent problems of the architecture built that way, a simple advice has to be obeyed: the system elements and rules must allow such variety of combinations of elements that is greater than the variety of requirements that might be sought (after the «Law of the requisite variety», Ashby 1953).

The Design Brief

By 1995, our office was not involved in design of mass-housing any more. However, many a «builder-enterpreneur» would spring up every now and then, asking for offers for design and realisation of quite large housing schemes. One such design brief was short and quite clear: to programme, design and build a housing estate of 2000 houses of 150+ sqm area each to be offered to the middle and high income unknown clients on the open market. The site is surrounded by woods, with the the continental type climate. Versatility of proposed designs plus customisation to individual clients would be appreciated. All preparation, design and realisation of houses must be contained within the period of two years. The offer, including the preliminary layout of the site, illustration of housing types plus the estimation of all-in-costs, was to be submitted within three weeks. Naturally, no professional architectural office could resist to at least consider making such offer.

I decided that our office should make the effort because we had the experience of this kind of work. It also seemed that this was the chance to find out what viability our CAAD research tools devoted to GIMS design had in practice. The design team consisted of four people, each investing a week of his time. These were: the project coordinator, the CAAD designer, the «traditional architect» and the surveyer making the bill of quantities. The structural engineers and experts for building physics were not required at this time as we knew in advance the physical characteristics of GIMS components and their conformance to the building regulations.

What Project Strategy and Tactics?

The proposed project strategy and tactics were based on the idea that the design and erection of houses shall be two-phased, and consist of the prototype phase and the instance phase.

In the Prototype Phase, design of a house for the unknown client presupposes the state of the uncomplete project information or an «ill-defined design brief». This would be the first stage of the project which would result in design and building of the house prototypes. In this text, the definition of a design prototypes would refer to a rough, generic design scheme. The physical prototype would be an uncomplete house, having the structure, some of the external walls, the principal HVAC blocks and conduits, and the roof with the possible shape amendments later.

In the Instance Solution Phase a real client appears, and after negotiation the brief is finalised, the detailed stage of design is completed. Thus, the «instance solution» would be finalised within the newly formed additional constraints. This is the state of complete project information or a «well-defined design brief.» The completed house would obtain the desired character, and all the idiosyncracies defined by the client.

What CAAD Support?

The selection of the CAAD tools for structural calculations, building physics calculations, CADDrafting, and visualisations did not present many problems. However, these programmes did not «design.» We had some specially developed programmes for this purpose: a) "GIMS-Expert" developed in 1986 (Petrovic et al. 1987), b) «GIMS-Face» developed in 1990 (Petrovic 1991), and c) "GIMS-DDS System" developed in 1991 (Petrovic, Svetel 1994). These programmes were aimed to the use in the preliminary design phases of family houses to be built in GIMS building system. featuring the same structural span in both directions (4.20 x 4.20 m), balconies up to 1.50 m, two floors, plus the pitched roof.

We decided to use the IMS-DDS design system as the main design vehicle, and ask the help of two other tools if and when necessary. The GIMS-DDS system is based on the idea of cooperation of computer «design agents.« Each agent is an independent computer programme dedicated to doing one or more specific tasks. It is defined by the respective function (what it does), the behavior it exhibits when performing (how it does it), and the type of relationship with other agents. Human participants are also design agents. We have developed the following generic classes of design agents: (a) generators, (b) transformers, (c) evaluators, (d) form presenters (i.e., 2-D and 3-D modelers) and (e) others (i.e. managers and communicators). Most of the agents (ARCH, LAYOUT-MANAGER, ROOF-PLANNER and PDP-AAM) are devoted to design of family houses in GIMS building system. Some agents are generally applicable (i.e. OYSTER, 3-D Viewer, and others).

ARCH. Generates house layouts upon the input information containing the required room-list, connections (between rooms) list, etc. Output: the of files containing information on layouts list.

Layout-Manager. Receives input information containing the layouts list. During the action sends out the requesting messages for consultation on orientation evaluation, subjective evaluation, request for making 3D representation of objects, etc. Output: house layouts.

Roof-Maker. A rule-based system. Generates all possible roof alternatives of a house upon the input information (3D building description without roof). Output information: alternative 3-D building description with roofs.

PDP-AAM-V.1.1. A 3-D Object-Verbal Transformer for the prototype level. Comprised of two feed-forward neural networks, each with a hidden layer. Together, they simulate the bi-directional association. The input/output layers are represented by a semantic differential and a 3-D editor, respectively. When the input is presented by the object verbal description via semantic differential, on the basis of the memory base (the «trained» hidden layer), PDP-AAM produces a 3-D object representation using a 3-D editor. The process can be reversed: if an object 3-D form is given, the semantic differential is produced.

EVALUATOR. An application of OYSTER. Makes inferences related to the contents of knowledge-base, and available facts. There exists several OYSTER knowledge-bases, such as evaluation of house orientation, evaluation of house character, etc. During the design session, new knowledge bases may be added.

Table 1. Examples of design agents

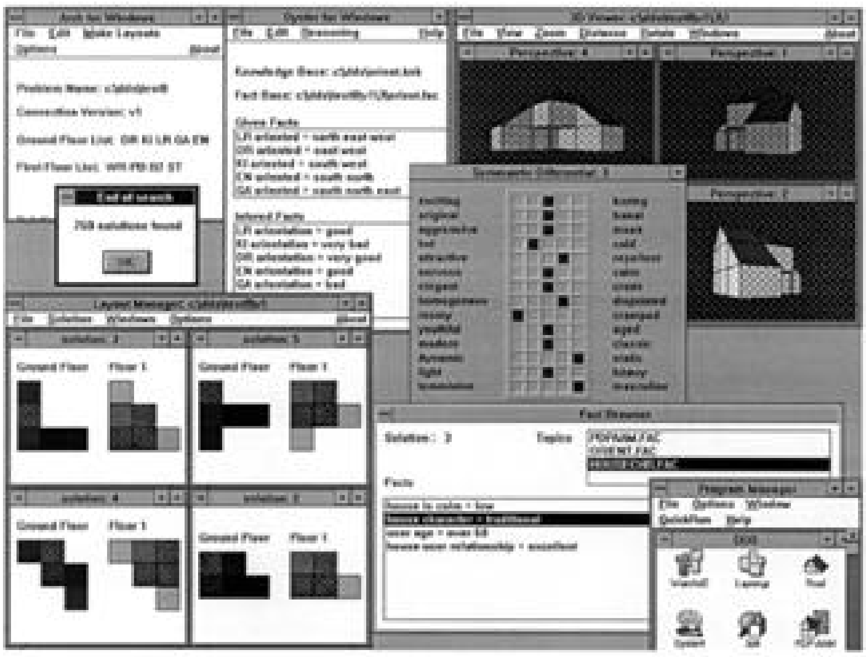

Figure 1. The GIMS-DDS window with active agents (ARCH, Layout manager, Roof-planner, OYSTER and PDP-AAM.

Figure 2. Development of alternatives of certain house type.

Figure 3. Elaboration of an instance solution with the componets from the GIMS Catalogues.

Figure 4. Perspective view of an instance solution.

Design Task 1: Proposition of a Prototype

Both GIMS-Expert and GIMS-DDS were suitable for this function, but had their differences. The slower GIMS-Expert was able to «design» a house and propose the «optimal» shape and a limited set of satisficing prototype designs in one go. The faster GIMS-DDS was able to generate the exhaustive umber of all possible solutions, but needed the separate generation and evaluation of alternatives.

Here, the selection of the «optimal» (instance) or the satisficing (prototypes) had to be done by help of an expert system embedded in the shell OYSTER. To put it differently, GIMS-Expert would design «bottom-up» while GIMS-DDS would use the «top-down» fashion. For this offer, only five prototypes and five instances were presented, with the clear presentation of all possibilities this approach entails. Using GIMS-DDS only, he following activities were applied:

i) Based on the given input (number of rooms, connections, and a desired house shape) ARCH would produce the combined ground- and first-floor plans, and present the house shape alternatives for a particular location in 2D.

ii) The house would be presented in a 3D editor.

iii) The Roof-Planner (a rule-based system) would generate all possible roofs for the selected house volume.

iv) The OYSTER, with the appropriate knowledge-base would evaluate the chosen solution alternative.

Design Task 2: Refinement of the Instance Solution

While the Task 1 was left to the CAAD Designer and his tools, the refinement in the Task 2 was given to the «Traditional Architect.» Not that he did not use various computer tools. They were needed in case that some exceptional structural details or and roof details would be applied and naturally, for drafting of all drawings. However, the «personal touches,» (special design of «add-ons»), elaboration of interior and exterior perspectives and other similar features were performed «by hand.» This was still the quickest (and cheapest) way to do it.

Conclusions

Were the computers beneficial in getting the design tasks done? Firstly, the computer tools we used allowed «3E's.» They ***e***xternalised design process, helped ***e***xplaining the design decisions and finally, ***e***nabled design participation. In our case, these were the important issues, and the computer tools did help in the preparation of the offer, with the high probability that they would do the same in the complete design process. The explicit design tasks and use of computer tools make this case of «computerised craftsmenhip» appropriate for presentation in educational environments.

Secondly, the computers really did the hard work of finding out the alternative solutions. It was quite comfortable to use the machine to «design» roofs, draw perspectives from any possible angle, and in the end, amusing to find out that the computers drew the conclusions we ourselves could have made.

How would the design of houses and other works be realised without the help of computers? To design and build a housing scheme of 2000 individual houses of 150-300 sqm of reasonably varied design in the continental climate in two years time is a complex technological task. I would not recommend doing it in the «traditional way.» If I had to do the same job again, I would recommend again the development of some kind of computer-based house generators and evaluators.

The GIMS-DDS system as a whole or the particular design agents only have been used occasionally in the educational environments as an illustration of generation and evaluation of design alternatives.

In my mind, our little excercise has proved again that «mass-housing design» is a very difficult discipline, where the critical problem was not in designing and building one or two thousand separate pretty houses, but in designing the system to build 2000 houses in the changing context, allowing that each of the houses be as diverse from the others and just what the client wished. I do not know how this could be done efficiently and qualitatively without the computers. Yes, I definitely think that the information technology ***is*** the design enabling technology.

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The design agents implementation environment was MS Windows 3.1 (Windows is a trademark of Microsoft Corporation), while the implementation language was Turbo Pascal for Windows 1.0 (Turbo Pascal is a trademark of Borland International Inc.).

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