

IMPROVING CAAD BY APPLYING INTEGRATED DESIGN SUPPORT SYSTEMS AND NEW DESIGN METHODOLOGIES

SEVIL SARIYILDIZ, HARRY VÖLKER, MATHIAS SCHWENCK
Delft University of Technology (The Netherlands)

ABSTRACT

This paper deals with the improvement of the current design practice by means of ICT (Information and Communication Technology) tools in the field of architectural design.

In the first part we make suggestions which can contribute significantly to improvements in the mentioned field. This includes:

- the development of Integrated Design Support Systems (IDSS)
- the application of new design methodologies in relation to IDSS.

In the second part we will discuss the topic more generally. Which other aspects have to be considered regarding the development of support software for architectural design? Which improvements can be reached by introducing advanced information and communication technology? Which changes are necessary in the promising relationship between architecture and computer science?

KEY WORDS

Computer Aided Architectural Design, Support Systems, Integrated Design Environments, Design Methodology, Architecture and Computer Science

1 Introduction

The building process has been changed significantly in the last years. Recent developments include the following trends, that are analysed in [StBR96]:

- principals work more professional
- increasing industrialisation of the building process
- demand for sustainable buildings
- increased use of information and communication technology.

Some other issues like the increasing importance of financial aspects or new strategies with respect to process management can be added. We can conclude that, at the moment, the building process is changing with respect to many different aspects.

Considering the architectural design process, we can make a similar statement. There are changes within the design process itself. Furthermore, some of the changes in other phases of the building process have direct effects on the design stage. Consequently, architectural design has to be adapted to the new situation.

With the conclusion that current developments in the building sector require new concepts for architectural design, the question arises in which fields solutions can be found. In this paper we will take into account two important aspects - the use of Integrated Design Support Systems (IDSS) and the application of new design methodologies in relation to these IDSS.

Furthermore, we will more generally analyse the relationship between architecture and computer science to indicate the reasons for its description as "difficult but promising".

When we look at the historical developments of computer science applications for the building sector, we can state that the use of computers in the field of architecture came relatively late compared with other scientific disciplines. The first CAD tools were developed and used by engineering disciplines such as mechanical engineering or aerospace engineering. Later at the beginning of the 60's some of the architects have also seen the importance and the necessity of these tools for their work. However, these tools were not directed to the needs of designers and architects. They were far more isolated from the architectural practice. They were developed for other purposes than architects needed. Another fact was that these tools were developed by computer scientists who naturally have no significant knowledge concerning architectural design. These tools could replace the drawing tables so far. Gradually the need and the use have grown. In the 70's we talked about "building informatics" and later in the 80's it became information technology for the building sector.

In the 90's the use of these tools was more spread out and the applications of ICT were implemented in the whole building sector. The range of applications differs a lot. Some use it still only for drawing purposes, others for representations. Furthermore, there even are attempts to imitate human intelligence to let the machine design as humans do. Another positive development is the fact that the designers came closer to the computer science subjects or to the computer scientists. Finally the knowledge about each other's domain increased and therefore the communication became easier between these two scientific fields. This resulted in many software and hardware products which are more convenient to use by architects and building engineers.

Generally, it is a matter of fact that the technological developments in every field of science have an influence on the society and therefore on the design and the design process itself. We are forced to think fundamentally about the influence of the rapid developments of ICT in architectural design. [VSSD96][Sari96]

What will be the way and the method to integrate the new tools in a design process to increase its efficiency and to reach better design results? What will be the most necessary, relevant developments for our sector? Where do we have to go with these ongoing developments? What are most essential needs for the building sector, especially for the designing architect?

We believe that there is no unanimous answer for these questions. In this paper we will introduce our approach which we consider an important contribution to solve existing problems within the concerning field of ICT for architectural design including conceptual (spatial form findings) and materialisation (building techniques related) phases of the process.

2 Integrated Support Systems for Architectural Design

We consider a complete automation of architectural design as an unlikely proposition and undesirable for the architect. Therefore, the general objective is to give support to the architect to improve the quality and to increase the efficiency of the design process.

So far there are different tools providing such functionality. Many software systems are in common use in the field of architectural design. The following statement is also valid for the field of architectural design:

"In the past four decades, civil engineering in general and structural engineering in particular have achieved remarkable successes in adapting successive generations of computational support technologies and developing computational tools for specific process steps." [Fenv95]

Nevertheless, there are no appropriate tools for many of the sub-processes. [Fenv95] describes this phenomenon as "readily identifiable individual process steps, that have been heavily computerised, to a point where these processes are, in effect, isolated "islands of automation" in a vast sea of essentially manual processes."

Furthermore, we can state that there is a significant lack of integrated systems providing a general support for the designer during the whole design process. So, the two key features are:

- development of tools for sub-processes where no appropriate software support is available so far, so that for every sub-process of architectural design where the use of suited software can lead to improvements, these tools has to be available.
- the integration of these tools into a framework in order to realise an open, modular, distributed, user friendly and efficient operating environment.

We have already stated that the main characteristic of the system is to give support during the whole design process. "Support" means, that the tools should provide functions to free the architect of routine tasks, to avoid faulty actions and to detect errors as early as possible, to support the architect by increasing the amount of available information, to support the exchange of information between different partners participating in the building process, etc. [SaSc96]

In [ScBr93] the term "integration" is described by distinguishing integration with respect to the following three dimensions:

- Data (Information)
- Control (Communication)
- User Interface (Presentation).

The data integration aspect of tools determines the degree to which data generated by one tool is made accessible and is understood by other tools.

The control integration aspect of a tool determines its communicational ability, i.e. the degree to which it communicates its findings and actions to other tools and the degree to which it provides means to other tools to communicate with it.

The user interface integration aspect is the degree to which different tools present a similar external look-and-feel and behave in a similar way in similar situations.

Integration has to be realised in all three dimensions. This avoids situations where limitations occur because of incompatible file formats, incompatible communication protocols or because of user interfaces that are not suited for the people working in the field of architectural design.

Instead of only developing design tools integrated system are also addressing the problem of the operating environment of these tools. The development concept is described in greater detail in [ScSa97].

Figure 1 gives a schematic view of an integrated environment as used in [Wo1f93].

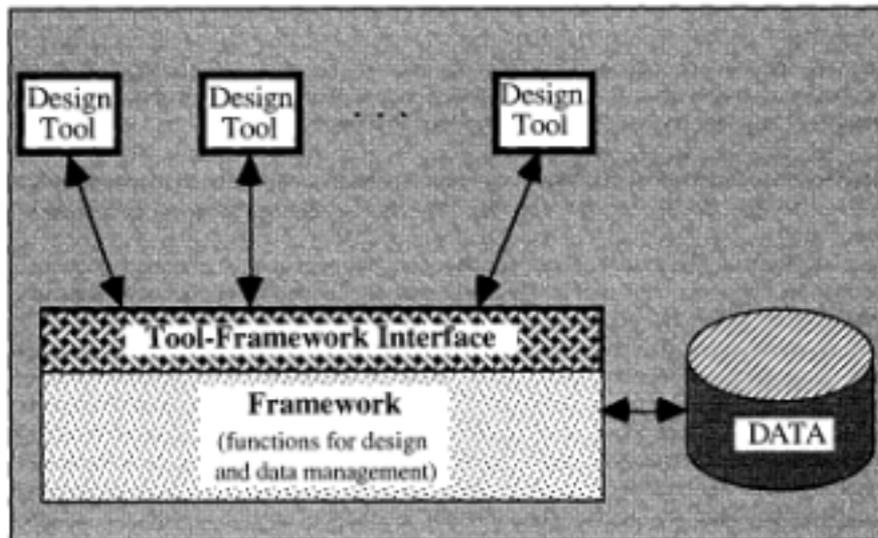


Figure 1: An integrated software environment

The framework provides general services for the tools. It realises functions for data management in order to organise design descriptions and to provide access as well as design management functionality guiding the designer through the design process.

The interactions between tools and framework take place according to functions of the Tool-Framework Interface. The definition of the interface is a key issue in tool integration because the effectiveness of tool integration depends on it.

Within the integrated environment different tools can be used. Tools that are newly developed can be implemented according to the facilities of the framework, whereas existing software may be integrated using known tool coupling methods.

3 New Methodologies for Architectural Design

One may argue that the development of design methodologies and design support systems are completely different fields which only have very few aspects in common. Besides the "trivial" reason, that every design tool is applied in a process following a certain methodology, others arguments can be given for our point of view, that it is essential to address both fields simultaneously. The automation of the traditional way of architectural design may lead to some improvements, but fundamental problems are not addressed e.g. communication, co-operation and management issues. Therefore, a lot of potential is not used. In order to come to fundamental improvements the application of advanced computer technology in the field of architecture has to be co-ordinated with improvements in the area of design methodologies.

Many architectural design processes have been successfully performed. Different methodologies have been applied, that are characterised by working without computer tools or by applying them only in a very limited role. In general these methodologies, that we will refer to as "traditional methodologies", can be considered a suited way of designing. On the other hand there are some inherent problems like for example:

- problems to combine different drawings in order to check the possibilities and to tune the various technological solutions
- impossibility to take into account the distinguished alternatives immediately during the discussions between architect, principal, consultants or authorities
- fast and simple exchange of information between architect and the other partners is almost impossible (at least very limited)
- architect has to take over the tasks of a co-ordinator and therefore less time available for his creative tasks because of the effort needed for the management of the design process - calculations during the modelling phase require much effort to be taken, but the results remain relatively rough and insecure.

A more detailed description is given in [ScVö96]. These problems and shortcomings may lead to significant quality and efficiency problems. Therefore we have to look for improvements to overcome these limitations. The fast development of science and technology offers some solutions.

In order to use information technology for architectural design effectively in an integrated way we will approach a new design methodologies is approached in [VoSc97]. "Integrated Architectural Design on the Basis of 3D Computer Models" is characterised by the following basic concepts:

- The process is based on an integrated manner of designing. Decisions are made as a result of discussions in a design team, where possible alternatives have been carefully evaluated.
- The whole design process is executed on the basis of a 3D model which is handled by means of computers.
- The availability of support software corresponding to the needs of the architect is one of the key features determining the success of the idea.

- In the design process there are different types of models. These models contain all relevant information generated in the design process. This includes the possibility to deal with several alternatives. Because of their availability at later stages of the design process, definitive decisions can be made "better" and highly qualified.

This methodology provides good possibilities for the integration of design and construction process. The co-operation between designers and consultants from different fields can lead to synergetic effects because of the different points of view and the different areas of knowledge. An extension of this methodology where the contractor participates in the architectural design process is also covered in [ScVö96].

So far we have discussed three different methodologies for architectural design. They will be referred to by using the following symbols:

A - Traditional Methodology of Architectural Design

B - Integrated Architectural Design on the Basis of a 3D Computer Model

C - Integrated Architectural Design on the Basis of a 3D Computer Model with Participation of a Contractor

The most significant differences occur with respect to the level of integration of the different participants. Consequently, the question arises if higher levels of integration can be reached. Such an approach is discussed in [VöSc97a] where we deal with architectural design within a "realisation team". In contrast to the building team as assumed in methodology C the principal participates in the design process as a team member. Therefore, his role is significantly more active. We will refer to this methodology as

D - Integrated Architectural Design on the Basis of a 3D Computer Model with Participation of Principal and Contractor.

All new approaches for design methodologies covered so far, i.e. B, C and D are applied with the objective to increase the degree of co-operation and integration between the participants. Issues of process control are not especially taken into account. Recent developments in the building practice show that the field of design management becomes more and more essential. This is illustrated by the fact, that managers are involved in many design processes. In general they take over tasks from the architect related to the process management, i.e. they act at a very important position in the decision making process during architectural design. Consequently, the whole design process changes significantly.

How can this be related to the methodologies covered so far? The first idea of extending a building team with a manager fails because incompatibility of the dominant position of a manager with the decision making processes on the basis of equal co-operation. It would more or less automatically destroy the team.

Another idea is the separation of the manager from the team, i.e. a manager who "manages" the building team of architect, consultants and contractor. The relative strong position of the team, as a group consisting of several people, compared to the manager as single person makes it impossible to guarantee the manageability of the process. Additionally, the character of the team changes in any case as for example the manager takes over the communication with the principal.

As consequence of the failure of these two ideas we have to discuss the participation of a manager in the design process at a low level of integration of the different participants, i.e. similar to the traditional way of designing. Such a methodology is described in [VöSc97a]. It will be referred to as

E - Management-Oriented Methodology of Architectural Design.

As a consequence, many advantages of the integrated way of designing are lost. Obviously, we would like to combine the primary advantages of both types of methodologies discussed so far, i.e. to realise a design process where the decisions are made on the basis of interdisciplinary co-operation in an integrated way and to guarantee the "manageability" of the process. As stated before, this requires to solve the problem of combining the key position of a manager with an integrated co-operation of the partners in the design process.

In [VöSc97a] we approach a methodology that fits this demand. It is based on the application of integrated support software, i.e. information and communication technology is used to combine the two dimensions of "manageability" and "integration between the partners involved". We will refer to this methodology as

F - Computer Supported Management-Oriented Methodology for Architectural Design.

The relation to the other methodologies is illustrated in figure 2.

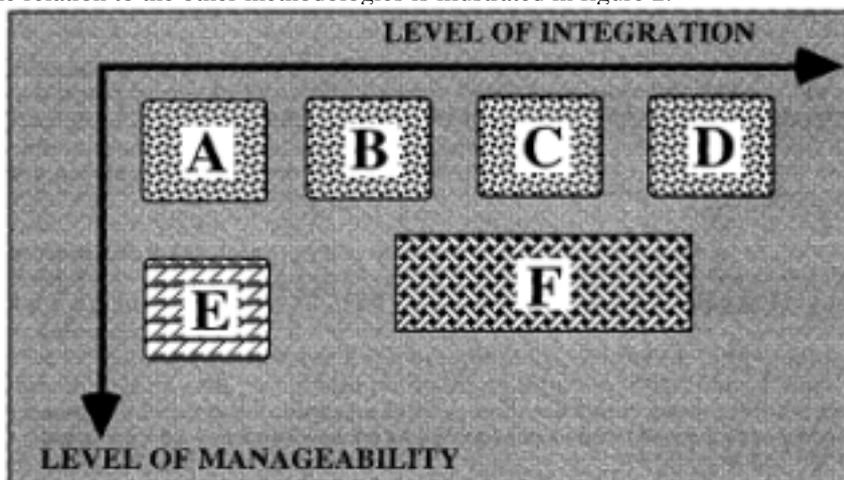


Figure 2: The relation between the covered design methodologies

Very generally, this methodology combines an "open" (separation of partners because of management-orientation) and "closed" (co-operation within a realisation team) approaches for architectural design. It only becomes possible by using integrated support software. [VöSc97a] describes this methodology in general and gives an overview about the subprocesses and data involved. Future research will extend and evaluate these results.

4 Future Developments in the Difficult but Promising Relationship between Computer Science and Architecture

The developments in the field of computer science have an inevitable influence on architecture. Therefore we have to deal with chances and problems of computer application in the building process. How did the computer science influence the architecture till now, and what is going to be the future of the architecture with this ongoing of computer science developments? In which way will these developments affect the position and the responsibility of an architect? We will discuss these questions and present our "vision of the future".

"Architecture is a science which is a mixture of an exact science and the art. The combination of these two important items makes architecture a difficult task . An architect has to combine these both primary elements in the design and in the same time while expressing the feeling of art, must take very good care of many other factors which play an important role in the building and design environment. The technical aspects on one hand, the social aspects on the other hand. " [Sari91]

Comparing this statement with common descriptions of the field of computer science where exact sciences like mathematics and electronics are considered to be the most significant elements, the contrast to the creative nature of architecture seems to be obvious.

One may argue that computer science is also related to interdisciplinary demands like perceptive psychology and ergonomics or that software development can also be considered a design process. However, these points of view are not very common, at least this is not the way how architects look at the field of computer science. Unfortunately, this "conflict" has effected the use of computer technology in architectural design.

Innovation in the field of computer science is only partly applied in the building sector. Applications are mostly restricted to conventional and traditional areas, consequently limiting the innovation in the building sector.

Regarding recent developments in computer-aided structural engineering [Fenv95] identified the interface between the problems and needs of civil engineering practice, research and education, on the one hand, and the emerging concepts and opportunities offered by computer and information technologies, on the other hand, as a key feature.

What are the factors creating a gap between these aspects? Some issues that we consider essential will be discussed in the following section:

- Architectural design is a mixture of various disciplines and very different tasks. Therefore, very different kinds of support software are necessary. Software has to be adapted to the specific needs of these tasks. In order to achieve this, these specific needs have to be compiled completely. So far they are at least partly "hidden" and consequently not considered in current software.

- One of the important advantages computers have to offer - the possibility to transfer information digitally over long distances in a very short time without copying drawings etc. is at least not commonly used so far. "Digital communication" could be a driving force for using computers in architectural design, i.e. a way, where computers become a communication medium for the partners in the building process. Recent research on areas like product data models and data exchange formats will contribute to this development.

- [K1er97] describes a difference in problem solving between engineers and architects. "Typical" engineers want to have a fixed framework and rules within in order to solve the problem, whereas architects usually start when everything is uncertain and try to stretch the limits to be able to use the solution in their imagination. The method of problem solving by architects is summarised as "sketching". Current computers do not have this ability, i.e. no computer support is available.

- In our opinion, architects have to develop a better "feeling" for the possibilities and impossibilities of computers. This must include the acceptance of computer technology as a factor in architectural design, i.e. to overcome positions of ignoring this technology. On the other hand, "euphoric" positions must be changed. A computer is only able to solve problems which are clearly defined. One may not expect the computer and the computer science professional respectively, to solve a problem in architectural design, if the architect cannot describe problem solving process. Modelling the problem is a fundamental requirement for its computational solution.

- Development and application of new ICT-techniques, methods and tools in the building sector is a very complex problem. In [SaSc97] three categories of tools are identified - design related tools, building techniques related tools and building process related tools. Contributions can be made by developing tools in the three categories as well as by dealing with their integration. As a consequence of the complexity of the process and the various interdependencies, many factors determine, whether a new development will be successful which are not always directly related to a specific development.

What will happen in the future? We expect a very positive development because of various reasons.

First, the necessity the use appropriate computer support in architectural practice will increase significantly. Buildings are becoming more and more complex, the influence of financial aspects on decisions in the design process will be stronger, the competition will force attempts to make architectural design as effective as possible. All these problems are very well-suited for computational support.

Secondly, apart from the application of information and communication technology new possibilities based on developments in fields like building technology and material sciences are applied in current architectural practice. Some architects go even further and participate in the development of new technologies. This trend will continue and also influence future software development projects. In this sense, we can consider architecture as a significant stimuli for future developments in these fields with a significant feedback to the degree of innovation in the building sector.

Finally, another factor will contribute in closing the gap between architecture and computer science. [Mave97] stated referring to the use of computers in architectural design:

"It is clear that as our young graduates enter the profession we can anticipate a massive increase in the use of the technologies in architectural practice."

So, the role of computers in architectural practice will increase in every case. It is the task of architectural education to prepare the students to these changes. There is actually no space to decide whether to support this process or to defend a design philosophy that avoids the use of computers, it is an irreversible process, but its progression will depend on current research as addressed in this paper.

5 Summary and Conclusions

In this paper we have discussed two possible contributions for improvements in architectural design - the developments of integrated design support systems and the application of new design methodologies that are directed to make the use of computers as effective as possible.

To overcome the current situation, where individual process steps have been heavily computerised, to a point where these processes are, in effect, isolated "islands of automation" in a vast sea of essentially manual processes [Fenv95], two aspects have to be covered. First, research has to be directed to evaluate the possibilities of support software for processes, where no software tools are existing yet or where only inappropriate tools are available. Secondly, these tools should be integrated in an open, modular, distributed, user friendly and efficient environment.

Integrated design support environments are a possibility to improve the quality and to increase the efficiency of architectural design. Compared to single tools their development is a complex process. On the other hand, the effort will be compensated by significant advantages as discussed in the paper.

If discussing the development of software for architectural design, the relationship between software support and developments of design methodologies has to be taken into account. In the first place, this is necessary to take into account current developments in design practice. Secondly, an identical transformation of the current design practice into software tools will limit their efficiency and consequently decrease the improvement that can be reached.

Architects have to participate actively in innovative development processes in the field of support software for CAAD. A more active position of architects will contribute to the solution of the problems in the relationship between computer science and architecture. The use of computers in architectural design will increase in the future. The challenging task is to have an effect on this development with own contributions and to take care of possible obstacles.

These ICT developments will have significant impact on the building sector. In addition to general quality improvements and efficiency increases other advantages are:

- better communication between the partners involved in the building process
- participation of the designing engineer in the whole design process becomes possible
- contributions in the industrialisation of the building sector
- development of assembly techniques
- robotising of construction processes
- contribution in the solving of environmental problems by sustainable buildings
- increased flexibility in the architectural design
- more variety in the architectural design

The incredibly rapid developments in the field of computer science and the emergence of this technology in all fields will have their effect on our subject area, architecture, our way of living, our habits and our cities; this will create fresh challenges, fresh concepts and finally new buildings and urban designs in the 21st century.

References

- [Fenv95] Fenves S.J., "Successes and further challenges in computer-aided structural engineering" In: Pahl P.J., Werner H. (eds.), "Computing in Civil and Building Engineering" (Volume 1) Balkema, Rotterdam, 1995
- [Kler97] Klercker J. af, "Implementation of IT and CAD - what can architects schools do?" Proceedings of the First International AVOCAAD-Conference on the "Added Value of Computer Aided Architectural Design", Brussels, Belgium, April 1997
- [Mave97] Maver T.W., "Added Value for CAAD in Education, Highlights of an Exciting 25 Years" Proceedings of the First International AVOCAAD-Conference on the "Added Value of Computer Aided Architectural Design", Brussels, Belgium, April 1997
- [Sari91] Sariyildiz S., "Conceptual Design By Means Of Islamic-Geometric-Patterns Within A CAAD-Environment" PhD-thesis, TU Delft, Faculty of Architecture, 1991
- [Sari96] Sariyildiz S., "Influence of Computer Science in the Next Generation of Architecture" Yearbook, TU Delft, Faculty of Architecture. 1996
- [SaSc96j] Sariyildiz S., Schwenck M., "Integrated Support Systems for Architectural Design" Proceedings of the 3rd Conference on "Design and Decision Support Systems in Architecture and Urban Planning", Spa, Belgium, August 1996
- [SaSc97] Sariyildiz S., Schwenck M., "Tools of an Integrated Software Environment for Architectural Design" Proceedings of the First International AVOCAAD-Conference on the "Added Value of Computer Aided Architectural Design", Brussels, Belgium, April 1997
- [ScBr93] Schefström D., Broek G. van den, "Tool Integration - Environments and Frameworks" John Wiley & Sons, Chichester, 1993
- [ScSa97] Schwenck M., Sariyildiz S., "An Integrated Software Environment for the Architectural Design Process" Proceedings of the International Conference on Applications of Computer Science and Mathematics in Architecture and Building Science (IKM 1997), Weimar, Germany, February 1997
- [ScVö96] Schwenck M., Völker H., "Modelling the Architectural Design Process - Analysis of Traditional Methodology and Approaches to the Future" Report, TU Delft, Faculty of Architecture, 1996

- [StBR96] "Geïntegreerde bouwconcepten - Van partijen tot partners: voorbeelden van kansrijke samenwerkingsvormen in de bouw"
Stichting Bouwresearch, Rotterdam, The Netherlands, 1996
- [VSSD96] Völker H., Sariyildiz S., Schwenck M., Durmisevic S., "The Next Generation of Architecture within Computer Science"
Proceedings of the 6th Conference of the European Full-scale Modelling Association (EFA)", Vienna, Austria, September 1996
- [VöSc97] Völker H., Schwenck M., "Approaching a New Methodology: Integrated Architectural Design on the Basis of 3D Computer Models"
Proceedings of the First International AVOCAAD-Conference on the "Added Value of Computer Aided Architectural Design", Brussels, Belgium, April 1997
- [VöSc97a] Völker H., Schwenck M., "Modelling the Architectural Design Process - Part II - Effects of Management Issues and Formal Descriptions"
Report, TU Delft, Faculty of Architecture, 1997
- [Wolf93] Wolf P. van der, "Architecture of an Open and Efficient CAD Framework"
PhD-thesis, TU Delft, Faculty of Electrical Engineering, 1993