41 FUTURE ICT DEVELOPMENTS

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The building sector is entering a new era. Developments in information and communication technology (ICT) have an impact throughout the entire life-cycle of a building, not only from a process and technical point of view, but also from a creative one. As a result of developments of advanced modelling software for architectural design, the gap between what the architect can envision and what the building technician or product architect can materialise is enlarging. Internet technology has already started to provide a closer link between the participants in the building process, their activities, knowledge, and information. Concurrent and collaborative engineering will be the future of building practice with respect to efficiency and quality improvement of this sector. The nature of the building process is complex. Not only in terms of communication, but also of information of the number of participants, spatial organisation, infrastructure etc. In the near future, soft computing techniques like artificial neural networks, fuzzy logic, and genetic algorithms will make contributions to problem solving aspects of the complex design process. This Chapter provides an overview of these and other future developments of information and communication technology within the building sector.

41.1 INTRODUCTION

Looking back to historical developments in the building sector the development of technology has always had an impact how people designed, built and lived in a built environment. If cast iron was not invented there would not be a Eiffel Tower or if the car was not invented, we would still have the narrow streets of the middle ages. There are numerous examples that show the impact of the technological developments on the society itself, by changing habits and the way of living, and, therefore, the changes on the built environment.

As in other sciences, ICT also influences the building sector. We are entering a new era. This will cause innovations, improvements and new challenges in this sector. If we focus on the design process as a part of the building process, we can generally say that there are four main domains of applications of ICT in the design process.

- *Creative design* orientated ICT (applied in the conceptual design or inception phase)
- *Materialisation* orientated ICT (building physics and building technology aspects such as calculating bearing structures and detailing)
- *Realisation* orientated ICT
- *Process and management* orientated ICT (linking the first three categories or activities)

Within the on-going developments of ICT, the rôle and the daily work of the people involved in the design process are both changing. Until now this process was cut into a few periods. When the architect designed the concept, this goes to the constructor, to work out the materialisation step, and afterwards to the contractor to build. There is always the supervisor, the building manager steering this process. We are now entering into a new stage. This process is not sequential any more, but more a network type which we call *information, communication and collaboration networking* in the design process.

41.2 ICT IN BUILDING DESIGN PROCESS

Initially computers were put into practice as a *tool*, as an instrument for achieving a specific result; a final drawing, an animation, a simulation, an interactive visualisation. Nowadays, computers have a different rôle as a new *medium*; next to the existing media within the architectural design process. Especially the widespread use of Internet and the developments of the Web have pushed the computer into the rôle of a medium.

In the near future, we can expect another shift in the rôle of computers in the design and building process, namely, as a partner.[a] ICT allows now to develop new techniques and methodologies using the computer as a *partner* by means of knowledge integration, decision support, and artificial intelligence. Decision support systems allow the computer to support the user through knowledge provided by experts or by the user herself. The computer can also be a partner when we teach it things it can reason with. It can even be a valuable and reliable friend when we let it solve problems not clearly defined, fuzzy, or uncertain. It can also assist in generating forms by processing information that influences the shape, supported by self-learning techniques. Here, artificial intelligence techniques like fuzzy logic, genetic algorithm and neural networks play an important rôle.

The ICT as Tool, Medium and Partner has the following support in the entire design process:

- Tool
  - 3D modelling
  - CAD (Computer Aided Drafting)
  - Presentation (Animation, Simulation, Composition, Rendering etc.)
  - Analysis
- Medium
  - Interactive visualisations (VR-Virtual Reality, Cyber Space)
  - Information processing
  - Communication (Internet Technology)
  - Collaborative & Concurrent engineering, CSCW
  - CAD-CAM, CAE, EEM (Enterprise Engineering Management) etc.
- Partner
  - Knowledge Integration (ANN-Artificial neural Network, Fuzzy Logic, Intelligent Agents etc.
  - Decision Support Systems-DSS
  - Advanced Modelling (Genetic Algorithms, Grammars etc.)
  - Intelligent Management

Finally, the ICT means is meant to support the designer in the design process to achieve the intended goal. This goal can be differentiated for different users. The flexibility and the efficiency of these ICT means are an important item in the future.

41.3 COMPLEXITY IN THE DESIGN PROCESS

Buildings are becoming more and more complex nowadays, not only in form and functions, but also in their infrastructure: their techniques and communications. Naturally, the design process is also becoming more complex. It is complex in the sense that many, often conflicting, interests and criteria are involved, and that many different types of expertise are required to find an optimal solution. Additionally, there is the uncertainty of the future use of the building, requiring the meeting of new criteria not defined explicitly at the moment of design. That means that a designer must have the ability to meet a certain range of criteria in a flexible way so that future demands are also met to a certain degree. The outcome of the design process has to fulfill different requirements of functional, formal, and technical nature. These requirements concern aspects like usability, economics, quality of form and space, social aspects of architectural design, technical norms or laws, and technical and mechanical aspects of the design.

Building design is a multi-actor, multi-discipline, and multi-interest process. Design is teamwork among architects, designers, and consultants for various fields, e.g., building physics, construction, material science, electrical engineering, acoustics, geodetics, building economy, and environmental engineering. The process of decision-making is often intuitive and based

a McCullough, M. (1996) *Abstracting craft: the practised digital hand;* Sariyildiz, S., P. van der Veen et al. (1998) *Computers as reliable and valuable partner;* Schmitt, G. (1999) *Information architecture: basics of CAAD and its future.*

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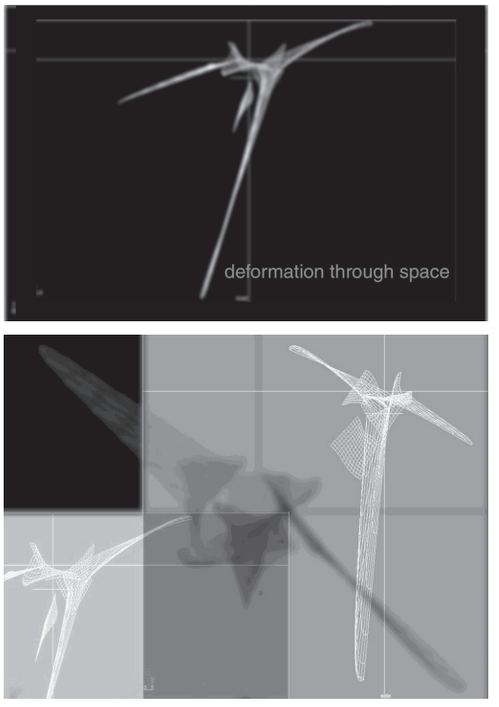
a Forster, K.W. (1996) *Rising from the land, sinking into the ground.*

on experience. Tedious discussions may occur in committees where all or many of the criteria are represented. The resulting decision is obviously a compromise, but it is often unclear how the decision was reached and whether better solutions exist. In this respect, the ICT tools and their integration form an essential component in the knowledge integration process of the various disciplines. As such, they are increasingly becoming a valuable and, hopefully, reliable partner in the design process.

To reach better communication and information exchange during the design process there were some initiatives to try out concurrent engineering in Europe. It was not successful for many reasons. Because the building sector in Europe is fragmented and still a bit old-fashioned in thinking concerning the innovations and technological developments. Concurrent engineering is now turning into collaborative engineering especially by the influence of Internet. The work can be continued any time, anywhere in the world. By means of VR the participants can communicate visually with each other. Therefore, is it worth-while to put effort into the developments of the broad-band technology also in Europe.

As mentioned earlier, in the building process we deal with complexity. There are many partners and knowledge disciplines involved. Information must be ordered and communication realised between various disciplines and people involved. Management of Information, Communication and ICT means are, inevitably, tools in the future of the building sector. Collaborative engineering techniques can be a good start.



387 Deformations

41.4 THE RÔLE OF ICT IN THE CREATIVE DESIGN PROCESS

The designer has to deal with three main categories of sciences, in the Netherlands called alpha, beta, and gamma sciences. Alpha sciences deal with the subjective world of beauty and ethics, as expressed by the artistic, intuitive soul. Beta sciences bring in the objective world of facts and logic, represented by the rational mind. Gamma sciences consider society and culture. Integration of these sciences makes the task of the designer more complex. The designer must have the skills to integrate the various disciplines of knowledge, involving besides the artistic form expression of the building also the dimensioning of the structure, building physics, applied mechanics, the calculation of structures, building materials and techniques, etc. The most famous designers, like Santiago Calatrava, are those who have the ability to combine these various disciplines in their designs as architect and building engineer.

When computers were first introduced in the building sector, the applications mainly concerned administrative tasks. Gradually their functionality extended to support repetitive tasks; nowadays, software applications are becoming essential tools for creative design, materialisation (building technical aspects), and the management of the entire building process. Already, for architects, like Peter Eisenman and Frank Gehry, employment of computational programs is an indispensable means, even if it holds no explanatory power over results.[a]

In respect to creative design, spatial software development for design aids during the last years influences form finding and spatial design of the creative designer. Designing architects are more and more using the 3D modelling software like MAYA. During the International design workshop in the Netherlands Architecture Institute NAI we experienced that the design tool offered to the designer has considerable impact on how the designer is stimulated by the possibilities of the 3D modelling software. The designer dares to design more complex forms and has more flexibility. To see the rôle of the new software for design, an experimental workshop was organised by the NAI in Rotterdam. Designing architect Lars Spuybroek guided the students for the design context in collaboration with staff of Technical Design & Informatics at the Faculty of Architecture, TU-Delft. Within few days time the students could cope with various software MAYA to design a stadium.

388 'Timeless', Folded surface

389 Guggenheim, Inside and Outside

41.5 ADVANCED MODELLING SOFTWARE AND ITS IMPACT ON PRACTICE

As a result of developments in advanced modelling software and its use for architectural design, the gap between what the architect or designer can envision on one hand and what the building technician or product architect can materialise on the other is enlarging. The Guggenheim Museum (figure 389) in Bilbao, Spain, designed by Frank Gehry, is a prime example. Designed using 'Catia', modelling software developed for the aerospace industry, the form of this design would have been much more difficult to establish using traditional tools and methods of designing. The architect is provided with a richer form vocabulary and more flexibility to realise spatial ideas on the computer. Design software has reached a point where it can stimulate the designer's creativity rather than impede it as has been argued in opposition to CAD software. Also in Europe, many architects have adopted advanced modelling software for their creative design, like Dutch architects Kas Oosterhuis and Lars Spuybroek.[a]

The developments in the field of building technology and building materials have not followed these advances in modelling software, so that they can no longer answer all the requirements and demands of the new architectural forms. ICT may play an important rôle in narrowing this gap. Electronic form information is transferred directly from the design model to computer-controlled manufacturing machines, as in the case of stone cutting for a curved wall. Unlike straight or even cylindrical surfaces, free-formed surfaces cannot be composed simply of standardised components; potentially each element may be of different size. This complicates the manufacturing process and causes cost explosion. Numerical or computer-controlled equipment enables custom components to be produced at a lower cost. Connecting it to the Internet, so that there is direct control from the design model further cuts cost. As custom manufacturing increasingly replaces standardised production, these costs will further decrease. Furthermore, as electronic catalogues are extended to include information on custom manufacturing techniques, possibly allowing designers to check manufacturability and price in the design phase, custom production will become more accessible.

41.6 COMMUNICATION AND COLLABORATION OVER THE INTERNET

As the Web and Internet technologies are filtering into every aspect of society, they will have enormous impact on building practice. Already, architectural offices are using the Internet to communicate with partners across the globe, discussing designs. As distances become smaller, architects are empowered to take on a global rôle. Examples abound already, like the world's highest skyscraper in Kuala Lumpur, Malaysia, designed by Cesar Pelli Associates in the US. The use of Islamic geometric patterns in the design shows a strong influence of local culture.

Global access requires new ways of managing the design process. Building projects are increasingly becoming teamwork, where no one person is solely responsible for a design. Well-defined control hierarchies and relationships are making place for more intricate collaborative processes not as readily planned and controlled. This requires an increasingly networked thinking that brings partners to closer inter-action but, without appropriate computational support, impedes the ease of overview and understanding.[b] Web-based document management systems serve as media for exchange of information between the collaborative partners and provide facilities for organising, viewing, and red-lining drawings and images.[c] These systems can also serve development and dissemination of tools supporting specific needs and processes, leading to integrated software environments as platform for various applications to communicate via the Internet.[d]

This evolution is founded on several universal Internet technologies, like TCP/IP, HTML, Java, and XML. Using them, it is pretty straightforward to create a Web application that runs on any platform. XML simplifies communication and improves agent technology. When exchanging XML-structured data, the only thing the partners need to agree on is the XML tag set

a Schwartz, I. (1997) *A testing ground for interactivity*.
b Lottaz, C., R. Stouffs et al. (2000) *Increasing understanding during collaboration through advanced representations*.
c Burchard, B. (2001) *AEC project management online*.
d Lottaz, C., R. Stouffs et al. (2000).

used to represent the data. No other information about each other's systems is required. This makes it simple for new organisations to join an existing structure of data exchange. Similarly, XML-structured data makes it much easier for an agent to understand exactly what the data means and how it relates to other pieces of data it may already know, thereby easing one of the challenges when writing an agent, that is, to interpret the incoming information intelligently and respond to it accordingly. Another advantage to the use of XML for structuring data is that it can easily be applied to existing data and information, for archiving or indexing such information. Unlike product model representations, XML structured data is easy for a human eye to read and understand, flexible in its application, and easily applied for specific purposes.[a]

Many disciplines are developing a framework for using the XML standard for electronic communications and data inter-change in their domain;[b] also the building industry (aecXML 1999). Considering the complexity of building projects and the un-structured and inter-related nature of the project data, the building community can benefit from a unifying strategy for data inter-change. This will not only make current data exchange and re-use practices more efficient, but will also result in savings through streamlining the worldwide transactions in the Architecture, Engineering, and Construction (AEC) community.

41.7 ICT IN ARCHITECTURAL EDUCATION

In the near future designers and professionals who educate the designers on the field of Computing in general, need to adapt themselves to rapid development. Up to now, in most CAD education at faculties of architecture, attention is paid to computers as a tool, partially as a medium for communication and information processing. Technological developments allow us now to look forward and go a step further.

It is necessary to introduce existing ICT means and techniques in education and the development of the mentioned subjects of ICT. In the future architects must be able to extend existing tools and integrate them into specific needs. The level of education must be pushed: to the level that the computer is not only a tool or medium, but also a partner in Knowledge Integration, advanced modelling techniques, and a support environment during the design process.

If these developments will be left to the others than architects, the architects will face the danger that they become slaves of the tools, not the boss; partially the same kind of problem is present with the commercial tools. No commercial CAD product supports the designer as it should. The user must learn the basic principles to use the software and take the advantage of it in an efficient way. This basic knowledge should be given to the architecture students in their first year.

On the other hand, the student of the future will be a mobile student working at any time from any place. Therefore, distance learning possibilities will gain an important rôle in the future for the academics, involved in the education.

41.8 THE IMPACT OF ARTIFICIAL INTELLIGENCE ON ICT ENHANCED BUILDING TECHNOLOGY

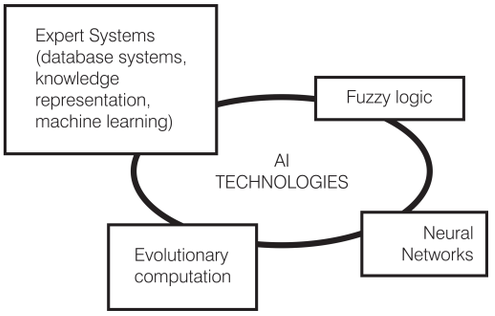
Design requires more comprehensive attention than ever. There is no doubt that the available building information must be used effectively. ICT can play a rôle in eliciting this information in a timely and exhaustive manner. Several emerging technologies have important relevance to the use of ICT in the building process and, ensuing, important implications.

As information and knowledge are being stored at a continuously growing pace, buried in gigabytes of records, they are becoming less comprehensible. Faced with difficulties of retrieving them and making them available in an easily comprehensible format at higher levels

a Tunçer, B. and R. Stouffs (2000) *Modeling building project information*.
b Cover, R. (2000) *The XML cover Pages (Extensible Markup Language)*.

of summarisation, this information becomes less and less useful. No human can use such data effectively and be able to understand the essential trends in order to make rational decisions. With reference to this phenomenon of information over-load, emerging technologies such as knowledge discovery and data mining offer a prospect of help. Knowledge discovery is inherently connected to databases: in inter-action with a database, a search for patterns or objects is performed, eliciting meaningful pieces of knowledge. Data mining provides means or methods to attain this knowledge. Among the most promising methods for data mining are artificial neural networks, fuzzy logic, and heuristic search methods like genetic algorithms. Collectively, these are referred to as 'soft' computing methods; heuristic search methods as 'evolutionary algorithms'. Artificial neural networks call for processing numeric data and building non-linear relationships. Fuzzy sets concentrate on representation of data at a nonnumeric level. The symbiotic co-operation of the two technologies results in an effect on the granularity of information.

These soft computing methods are receiving growing importance in almost every field, including building technology; slower there. Presumably, the basic reason for this is the difficulty of formulating building technological problems in a way that they become convenient for artificial neural treatment. However, these methods are especially important in the building sector, as they can handle information in various forms. A unified representation for artificial neural networks and fuzzy logic is already established.[a] It is likely that the communication between building technology and soft computing technology will be much easier than before;, due to the possibility of processing information at hand more human-like in coming years than previously.



390 Some basic AI fields of importance to ICT developments with impact on building technology.

Currently, this information processing, in combination with knowledge base systems, is mostly introduced by way of expert systems or decision support systems; in most cases unsatisfactory. In the future, we may expect computational intelligence systems to play a more important rôle.

Intelligent systems are increasingly replacing conventional systems: see intelligent manufacturing and intelligent design technologies. Some basic Artificial Intelligence (AI) fields associated with the emerging technologies connected to ICT development are indicated in figure 390. In order to cope with the demands of information acquisition and information handling of these intelligent technologies, new methodologies and techniques are being developed. Besides knowledge discovery and data mining technology, agent technology is an example.

An agent is a software program designed for a specific purpose or functionality, acting autonomously to some extent; may be intelligently too.[b] Agent technology is closely associated with ICT: agents are generally conceived for communication with other agents or software and for transmission to distant computers. The Internet allows a distant computer to be any machine on the globe. Agents are especially promising for mining databases. As an example, a fuzzy engineering agent can interact with a building design database in order to identify various trends of engineering or architectural nature. In connection with virtual reality (VR), agents can assist in design by providing sufficiently realistic feedback early in the design process. This should ease early integration of design components, particularly in collaborative design.[c] Especially for collaborative design, agents have an important rôle to play to assist participants in their task or communication, or to offer additional functionality in project-management applications.[d]

41.9 CONCLUSIONS

Ongoing development in ICT has an important impact on the design and building process. Designers can allow ideas and intuitions to take physical shape in ways not possible before.[e]

a Jang, J-S., C-T. Sun et al. (1997) *Neuro-fuzzy and soft computing: a computational approach to learning and machine intelligence*.
b Jennings, N.R. and Woolridge M.J. (1998) *Agent technology: foundations, applications, and markets*.
c Abarbanel, R., E. Brechner et al. (1997) *FlyThru the Boeing 777, formal aspects of collaborative CAD*.
d Stouffs, R., D. Kurmann et al. (1998) *An information architecture for the virtual AEC company*.
e Forster, K.W. (1996) *Rising from the land, sinking into the ground*.

At the same time, building technical developments are lagging behind. Alternative, innovative solutions have to be adopted. At the University of Cincinnati, *"all building trades (plumbing, tiling, painting) were carried out through a three-dimensional co-ordinate numerical control system implemented by an electronic laser transit on the site"*.[a] Future ICT developments for architecture and the building sector will be in the field of knowledge integration and decision support environments leading, finally, to ICT support in the entire building process, from initiative until demolition. Collaborative engineering will pervade the building design process. By these technologies, the branches of scientific disciplines will come closer than ever before to an integration. In the future, each participant in the design process will need to be able to make her own computer model in order to build up specific knowledge within it and use it as a partner in the design. Developments in the software industry show that if software firms provide the software core, architects and building engineers will be able to develop their own application tools according to specific requirements and needs. Independent of existing tools, they will be even free to create their own language of activities. Ongoing developments of Internet technology require other ways of design management and communication (data and partners communication) in the building process.

a Zaera-Polo, A. (1996) *The making of the machine: powerless control as a critical strategy*.