The Impact of Computer Aided Architectural Design on Physical Reality

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Computer Aided Architectural Design (CAAD) has produced three types and three generations of CAAD researchers, teachers and practitioners. The three types – CAAD inventors, implementers and users – benefit from the constantly improving computer technology. The three generations – CAAD pioneers, trendsetters and educators are in a more difficult situation as the attitude towards, and the knowledge about, Computer Aided Architectural Design in the general public and in the professional community is unstable. To explore the impact of CAAD on physical reality and to discover future challenges, it is useful to look at the pioneers of CAAD, as they often combine in one person the characteristics of the development that occurred afterwards. Tom Maver is one of the premier examples. The paper presents thoughts on CAAD teaching and research and contrasts them with the professional reality at ETH, in order to explore the impact of CAAD on the physical reality.
1. Introduction
The nature of CAAD was multi-facetted from the beginning. In the professional community, the perception ranged from a welcome presentation instrument to an expensive Trojan horse with unknown effects; for the universities, it meant the introduction of cost-intensive research and teaching laboratories, but also the possibility to interact with other disciplines and sciences, often for the first time. For students, it meant a shift of view and educational focus. But while the architect of the last century had to know much about machines, society, technology and materials, the architect of this century will need to know much more about the nature and properties of information – be it in its interaction with physical material or in its potential to create new architectural worlds. CAAD is providing the intellectual space, as well as new learning and teaching environments. CAAD has strengthened architectural education. The more emphasis design teaching places on new methods of systematic learning and knowledge transfer, the more it will be able to transmit in a given time the necessary design knowledge that has increased significantly over the past decades. Possibly, architectural education will become more similar to medical education: appropriate methods, a rapidly growing body of knowledge and a holistic approach towards the discipline could be taught. As early as 1991, Tom Maver suggested a form of architectural education that is known as blended learning today.

CAAD will continue to play a crucial role in the future. This could mean teaching a new digital language rather than a traditional discipline; to enable on the one hand communication between methods, knowledge and architecture, and on the other hand curriculum internal communication with history, technology, design and professional areas. CAAD research will become more significant than ever before, because excellent education depends on excellent research. As a result, the architects of this century will become creators of a digital design culture in education and research and participate in the development of information architecture. Actually, this has been Tom Maver’s area of research and teaching for more than 2 decades [1].

2. Computer aided architectural design teaching
Design teaching is a unique activity and quite different from other teaching approaches. CAAD teaching has long entered the mainstream of design education. But it has not in any way reached its full potential. Automation and AI in design as original aspects of CAAD have regularly lead to heated debates between “real” architects and “believers” in CAAD. Once feared as a possible replacement for the core activity of architects, automation soon found its place in the support and faster execution of drafting, modelling and construction tasks. Yet the vision of automatic design machines that would
rival the result of human design activities in quality has not been realized to date. Quite the opposite, the design generation and automation approaches of the 1980s and early 1990s have given place to more conventional design techniques, which are, however, supported by much better digital technology. In other words, as the expectations for total design automation vanished, simple instruments in daily design life have matured to a degree that it might in the end be faster to use those relatively primitive tools, rather than being driven by design automation systems. It is not surprising, that similar developments occur in other fields where creativity and task automation play a major role, such as in finance and engineering.

2.1. Future design teaching

Future university design teaching must be oriented towards posing and answering relevant questions of individuals and of society rather than solving specific problems. With that in mind, disciplinary knowledge and skills will attain a different meaning and transdisciplinary knowledge will gain in importance. With few exceptions, the roots of digital design methods and programs are not located exclusively in architecture, but rather in computer science and engineering. This offers the chance to re-establish a dialogue with these disciplines. A few examples: Finite element analysis programs, complex geometric modelling systems from the airline industry, rendering and animation packages from the entertainment industry, financial analysis packages from the finance industry are a normal part of today’s architectural education. On the other hand, the idea of the intelligent design support system has caught the attention of related disciplines. Using and understanding the tools of others is the first step towards transdisciplinarity.

Of particular interest in this context is the new field of information architecture design. According to the information design consultant Richard Saul Wurman, graphic designers, creative information technologists, writers and journalists have the potential of becoming information architects or designers (2). Information architecture design will shift the emphasis more towards the virtual aspects of architecture and will therefore be more open towards methods for virtual design.

2.2. Multidimensional design teaching and learning

Effective design teaching and learning requires continuous streamlining of the subjects taught, as new topics enter the curriculum – CAAD being one of the more time-consuming. In the past, it was believed that only one particular curriculum with carefully worked out vertical streams could lead to satisfactory education results. Yet a comparison of the best architecture schools worldwide suggests that the quality of the design teachers, the infrastructure and the context might be more important than a particular curriculum structure. Analyzing the curricula of successful architecture
schools, we find that the design core is increasingly supplemented by digital techniques. At the same time, outstanding schools afford the luxury of design and digital design research. Firmly based on a design core, they are strong in technology, business and other transdisciplinary aspects.

The brute force approach to teaching and learning – by constantly adding new topics – has reached its limits. The commitment of ever increasing portions of the curriculum to design or technology or history will not lead to satisfactory solutions either. But looking into other fields of study might help: each discipline or science has an analogy to core and support studies.

It is therefore necessary to expand the capacity to learn more in a given time frame. Neuroinformatics slowly reveals details about the process of learning and its interaction with teaching. On the other hand, disciplines such as computer science and mechanical engineering are discovering the advantages of architectural project based learning and intensive interaction between teacher and student. Yet the more the field of architecture advances, the more difficult it becomes to simultaneously create the necessary detail knowledge and the overview indispensable for successful design.

3. Computer aided architectural design research: information architecture

It is not appropriate for this paper to re-visit the entire set of CAAD research topics. Instead, the focus will be on one promising field that is interesting both from the standpoint of fundamental research and for practical purposes: information architecture. As information architecture we describe a structure between physical and virtual architecture, influencing and at the same influenced by both physical reality and virtual reality. A necessary condition is the extension of the definition of architecture towards more virtual components. Information architecture thus becomes an essential relief from the restricted physical availability of space, enabling us for the first time to expand our horizon beyond the physical limits while staying in touch with reality.

CAAD was the first step in this direction. It started out with high expectations towards supporting creativity and design, as well as the following processes. Later it moved more towards a utilitarian direction. Optimization of specific tasks and the slow, but constant disengagement from the core of the design process were the result. As soon as CAAD was no longer seen as a competition to traditional design methods, many of the original ambitious visions were abandoned and replaced with practical ideas. Yet looking at the recent international FEIDAD or Netzspannung competitions, one can be hopeful that CAAD does support creativity [3,4]. These competitions are the best proof that CAAD and Digital Design Education have become a successful part of today’s architectural teaching.
and learning. They also point towards the field of information architecture, based on three successful research directions:

- **Geometric modelling and geometric reasoning research**: this formed the foundation for CAD programs, which today dominate the instrumentarium of architects worldwide.
- **Artificial Intelligence research**: this brought a better understanding of design activities and opened the field for new support methods.
- **Design methods research**: this brought much needed knowledge into the nature of design.

Future CAAD research will naturally develop bottom-up through the interest of the individual researcher, but at the same time, some themes of general interest must be supported top-down. Such themes could be:

- **Systems engineering research**: integration of knowledge and experiences from different fields into one result.
- **Mathematics**: deeper views into the nature of design, a re-examination of the advantages of automation.
- **Biology**: in-depth research into analogies between biological and architectural design processes.
- **Neuroscience**: more research is needed into the activity of design itself and into design learning, together with psychology and neuroscience.
- **HCI**: deeper understanding of human-machine interaction and communication calls for better relations primarily with computer and communication science.
- **Simulations**: the area of performance, simulation and predictability of the building is far from being solved. Physics, mathematics and computer science are natural partners.
• Sustainability. In reducing excessive CO₂ production, solving pollution problems and preventing possible climate change, architects and planners can play a crucial role. Obviously, earth sciences, environmental sciences and physics are necessary partners.

• Marketing. Design marketing and communication calls for close cooperation with those disciplines.

The result of architectural research must be used to build up a reliable architectural body of knowledge, without which the study of architecture will not be attractive in the future anymore. If architectural research does not lead to visible success, architecture as an academic field will become fair game for university administrations that may want to move it out. If, however, the research leads to results, information architecture becomes much more realistic.

4. CAAD reality: the planning of science city

ETH Zurich has two physical locations – ETH Zentrum and ETH Hönggerberg – and one virtual campus – ETH World [6]. ETH Zentrum is located in the centre of the city and is home to the engineering science, social science and environmental science [7]. In theory, CAAD should be of enormous help in the planning and design phase of buildings. This is what we teach our students and this is what the success of the CAD and database firms is built on. It is necessary to explore the relation between theory and reality, taking as an example the planning of ETH World, ETH’s virtual campus, of HCI, ETH’s largest building construction and of Science City, its newest campus. Is CAAD teaching and research in contrast or in accordance with the professional reality, and which effect does it have on physical reality?

4.1. ETH World: all CAAD

ETH World started in 2000 with an international master plan design competition. Participants from five continents took part. Without CAAD education most entries to the ETH World master plan competition would not have been possible. A wealth of ideas and proposals emerged, which can still be visited and serve as a benchmark against the idea of the winning team that is under implementation in stages since then [8]. The realization of ETH World is progressing, naturally with digital methods. It has created Switzerland’s largest wireless LAN installation with more than 7000 students using the digital services of the information space. ETH World has already caused a better utilization of existing infrastructure and to a growing support for blended learning. It could be seen as an anti-architecture development. Instead, it has begun to improve the long-term design development. It allows for better design of new buildings and is an important bridge between the physical and the virtual. Tom Maver in his 1998 talk From Virtual Reality to Real Virtuality predicted this development [9].
4.2. ETH’s largest building: some CAAD

ETH Hönggerberg is located 8 km from the centre in a recreational area north of Zurich, where the natural sciences, life sciences, architecture and building sciences are domiciled. The decision to place the life sciences on the Hönggerberg fell in 1985 – long before the advent of CAAD in Swiss practice. In 1988, Mario Campi won the competition for the chemistry and material science building. But construction could not begin until 1996, because the inhabitants of the surrounding city quarters heavily opposed the project. This resulted in a delay of 4 years. The building will be completed in 2004 at a total cost of 625 million $ [10].

The story of the use of computers in this long process is the story of CAAD in Switzerland. When the Board of ETH initiated the project, Professor Herbert Kramel was the first and only CAAD pioneer at ETH. When the competition ended in 1988, ETH established the first Chair for Architecture and CAAD in Switzerland. The Chair developed CAAD Principia courses, types and instances programs and other intelligent design and modelling aids [11]. They were used to model the new HCI building, as it was named. For realistic VR simulations of the HCI building, we developed special support software. Finally, the HCI visualization project became a driving force behind the establishment of the ETH Zurich visualization dome in 1998. An interesting irony: simulations of a virtual building leading to a new physical structure.

Two general contractors were responsible for the construction process: Karl Steiner AG from 1996-2001 and HRS from 2001-2004. The ETH as
The building owner represents the Swiss Federal Government. ETH uses a commercial database management program to keep track of the more than 100,000 documents generated during the design process. A facilities management program supports the maintenance of the entire building. Yet unfortunately, little of the information that was needed to design and model the building a decade earlier remains in useful digital form for today’s facility management needs and for the building management information system. The ZIP Cube, a construction-oriented document management system developed by Professor Paul Meyer, was evaluated but could not be used in the project [12].

4.3. Science City Zurich: mostly CAAD

According to the SPINE (Successful Practices in International Engineering Education) study of 2002, the infrastructure of engineering schools is seen as a critical success factor, right behind the quality of professors. ETH Zurich is a world leader with regard to its infrastructure [13]. In the progress from traditional structures towards a modern university environment, ETH Zurich has reached a crucial point: The planning of ETH’s 21st century infrastructure, named Science City [14]. With a new financing and development system, ETH plans to start the first building in 2005 and to complete the campus in 2010.

Students, staff, professors, inhabitants of the surrounding areas, politicians and alumni have the opportunity to participate in the design of Science City. It is clear that this is not merely a construction effort, but an endeavour that needs the support of the ETH community and of all citizens of the region. A first step was the establishment of an electronic forum to spread...
ideas and to arrive at better-informed design decisions. The forum has
developed into an electronic agora that allows barrier free access to the
discussion around the design of the new city. Indeed, we have come a long
way since the beginnings of CAAD.

Re-visiting the first steps of Science City’s development, the use of
CAAD was limited. Certainly the architect employed a wealth of digital
presentation instruments, but in the end, due to time pressure, the model
was build physically and not even VR walkthroughs were produced. It is
interesting that, while these forms of presentations were sufficient in the
beginning, the stakeholders are now calling for more advanced visualizations
and presentations.

Virtual parts of ETH’s new Science City will be the Villa Garbald by
Gottfried Semper in Castasegna, in the southernmost part of Switzerland,
and the Architectural Library of Werner Oechslin in Einsiedeln, designed by
Mario Botta. As any modern city, Science City needs places of reflection,
completely digitally connected to the city, but remotely located. The Villa
Garbald and the Architectural Library of Werner Oechslin use the newest
communication and display technology to stay in touch with the ETH.

5. Conclusion

Computer Aided Architectural Design has matured to a degree that it is
almost completely integrated in the processes of design, construction and
management, with one crucial and noticeable exception: The early – or the
real – design process. Although it has been the focus of hundreds of
research projects, design support programs have not really made significant
inroads into design practice. In spite of this, CAAD education is not a
luxury, but an absolute necessity for the architects of this century. Only if a
broad population of architects and designers is familiar with all aspects of
CAAD, it will eventually become a natural partner in the design process.
CAAD opens the opportunity for the development of a new culture, in
which the digital, the virtual and the physical coexist seamlessly and support
each other to form a new whole.

The HCI project, lasting for 20 years, demonstrates the different speeds
in the development of architectural design, CAAD methods, CAD
instruments, construction management and facility management. The ETH
World project shows that and how a virtual infrastructure can be
envisioned and realized within a short period of time. This indicates that
CAAD education has produced a universally understandable language in
which designers of all backgrounds can communicate.

ETH Science City takes this concept to another level. It shows that the
university environment of the future will contain a wealth of physical and
virtual places, connected in a modern city planning effort that encompasses
both the physical and the virtual. In fact, one without the other could not
exist anymore.
Finally, this has implications for architectural education. Architects are no longer restricted to the creation of physical structures or individual objects. CAAD, relying both on human knowledge and connected memory, will gradually replace conventions such as internationalism, a common architectural language or ideology. The pioneer Tom Maver has predicted this development throughout his career. He will be right.

References
5. ETH BlueC project http://blue-c.ethz.ch/ [18-1-2004]

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