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Potential and challenges for research and education

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Computation in Architecture: Potential and Challenges for Research and Education

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1 Introduction

Modern computer technology has a decisive influence on the building and construction industry. A vast range of digital tools are nowadays available to all disciplines involved in building and construction processes. This impacts not only the planning and manufacturing processes but also the quality and the appearance of the results that *can* be achieved. Examples include the complex geometries of designs and the simulation of requirements concerning statics and building physics or, also relevant, the organization and communication as part of the project. Designs can today become directly and precisely manufactured via digital fabrication. In this context, buildings and constructions are promptly realized which would not have been feasible without state-of-the-art computational tools. The last decades have been typically characterized by an architectural and design language borne from the capabilities of this technology.

The actual added-value created, by the application of computer-based tools in architecture, is the topic of an ongoing controversial discussion. Only a few decades have passed since they were introduced in the course of the Digital Revolution. Compared to the wide range of new methods and possibilities, we have very limited experience as to the efficient and sensible use of these technologies. In the past, the focus was mainly on the digital tools themselves. Studying them resulted in new developed strategies which were then transferred to exemplary implementations. The future relevance and acceptance of digital strategies will depend on an obvious added-value for architecture. Next to architectural-aesthetic possibilities of geometries or complex structures, an added-value might lie in an increase of design

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and in construction process, efficiency as well as a higher quality of achievable results. In this context "performance" has become an established term. In order to increase the performance, it is necessary to focus considerations not on the capabilities of computer tools, but on the requirements of the building project.

Digital tools constitute a new challenge for architects, planners, and engineers. In addition to the traditional proficient knowledge in their fields of expertise, professional knowledge of information technology (IT) is increasingly required. Classical career profiles like those of architects might have to be reconsidered with this background and new disciplines might become necessary such as expert planners to become the interface between architects and IT, involved in the planning and construction processes of buildings. Today we face the third digital revolution, a comprehensive digitalization and intensive networking of our environment. The current debate is driven by concepts like: "Internet of Things", "Industry 4.0", and "Big- or Smart Data". It also affects architecture since, in the front of an increasing building automation, the influence of computer technology goes beyond the planning and construction phase and now also has an impact on the building's operating phase. Computers make "intelligent" control of essential functions possible and often represent the core of "smart architecture". This however results in new responsibilities for architects. Traditionally, the architect supervises the design phase and the construction processes of a building up to the handing over to the owner. Automation now means new tasks during the utilization phase of the building. Within the matching of intelligent automated building technology with the building's usage, and, in the definition of control parameters according to user requirements, there lies a new responsibility [1–5].

2 Research and Teaching

Education is particularly important. Appropriate teaching equips the professionals involved in the building processes with the necessary IT expertise. This is also relevant since, preceding Building Information Modelling (BIM), the computer has taken up a central position as a communication and working platform. The new requirements become recognized nowadays and some universities are already offering study courses in architecture with a focus on digital tools. An example is the post-graduate program: "Master-Computational Design and Construction" (M-CDC) at the East-Westphalia University of Applied Sciences in Detmold. Not only is the mediation of existing knowledge important, nonetheless, the rapid introduction of computer technology into architecture brings up many new open questions. This is where research plays a key role. The better we understand both the chances and risks of the technology, the better we can develop uses that will lead to added-value in architecture.

3 Research ThinkingSkins

Implementations of digital controls for adaptive building envelopes are investigated in the research under the title “ThinkingSkins”. The façade has a substantial influence on the appearance of a building. Beyond that, it also plays a key role in the energy performance and the user comfort of a building as it mediates between outer and inner spaces [6]. This means coping with constantly changing external influences and interior requirements. The dynamic adaptability of the building skin increases its efficient performance. Today, external influences can be measured with sensor technology which triggers appropriate digital reactions. They are called appropriately: “responsive facades”. Computer technology allows for the control of individual, reactive functions and their interconnection. The matching of the interactive reactions with the use of the building represents a challenge for the design of the façade. The study of ThinkingSkins is based on the assumption that strategies of digital, rule-based design can contribute towards an effective total system of individual reactions. The aim of the research is a higher performance of building envelopes reached by the design ability of self-regulating complex systems that take indoor requirements into account [7].

A special potential lies within the linking of research and teaching. Therefore, some studies in the research of ThinkingSkins are carried out in collaboration with students. Several workshops were held in this context on the topic of responsive Building envelopes. An example is the workshop “façadetronics”. It was part of the efnMobile program, a workshop series by the European Façade Network and was held in November 2015 at the East-Westphalia University of Applied Sciences in Detmold. The workshop was inspired by the conference “facade2015—Computational Optimization” and was part of the local façade week. Students of the postgraduate Master courses International Façade Design & Construction (IFDC) and Master-Computational Design and Construction (M-CDC), as well as students of the façade Masters at University of Luzern attended the workshop. The aim of the program was the development of innovative automation concepts for the facade. These should also, in addition to a theoretical examination, be implemented and studied in the form of prototypes. For carrying out the task, international and interdisciplinary teams were formed (Figs. 1, 2, 3, 4, 5, 6 and 7).

The starting point of the investigation was not based on the options of available technology, but on the existing functions of the building envelope. Therefore, each team got a façade function to edit which was assigned by lottery. The selection of functions was based on a model developed by Klein [8], the façade function tree. For a focus, the selection of functions was limited to those in the context of the influencing factor, that is the sun, such as glare protection or sun shading. At first, the teams examined how the corresponding facade function has been traditionally implemented. This included both, the analysis of existing designs, as well as the determination of physical principles. On this basis, the first ideas arose on how the

Fig. 1 Workshop "façadetronics"

Fig. 2 Team discussion as part of the design process

informing and activating of facade structures may contribute to the fulfillment of the respective function. The identification of relevant information and the appropriate sensor technology was as relevant as the development of active components with built-in actuator technology. It was also part of the task to develop a concept for the control strategy. It had to be decided; how gathered information is to be transferred

Fig. 3 Digital design of the structure

Fig. 4 Realization of complex components by digital fabrication

Fig. 5 Prototyping

Fig. 6 Implementation of the Arduino-control

Fig. 7 Project DOUBLE LOUVRE prototype

to a corresponding reaction of the facade. The challenge for the students was to develop both, a concept for the physical construction as well as for its digital control. On the physical level, the teams were faced with the merging of kinetic and electronic components. Digital design strategies were applied and led to 3D-models of the structures. The subsequent digital fabrication enabled the realization of complex components. The concepts for the digital controls were first graphically developed and visualized by dependency graphs. A later implementation of the control in the prototype was based on the Arduino platform.

As a result, any concept was graphically displayed on three posters. The first poster includes the analytical examination of the façade function. The second poster documents the concept and its principle of construction. The visualization of the design is based on the 3D-models created earlier. The third poster illustrates the development and installation of the prototype. The prototype itself is an important part of the design result. The implementation of the prototype took place within a prefabricated model framework. Through this, the students were able to concentrate on the construction of their active structure. By specifying the prototype size and shape comparable and combinable results were obtained. The model-scale prototypes allow the physical visualization and verification of the drafts functional principles.

For example, a project within the workshop led to the idea of a "PARACHUTE FACADE". The aim of this construction is a self-regulated shading. The design of the students Amir Saadatfard (M-CDC) and Bahman Bidmeshki (IFDC) proposed a grid of rectangular frames that is equipped with stretchable fabrics. A stepper motor is positioned at the center of each frame, supported by the fabric itself. It opens or closes the textile according to the daylight situation. The intensity of sunlight is measured per item, based on the information gathered by photo-resistors. The information becomes transformed into the reaction of the stepper motor by a microcontroller. By embedding sensors, actuators, and computer control, each frame performs as an intelligent device that can respond to a changing intensity and position of the sun. The project "DOUBLE LOUVRE" by Ivan Cakaric (IFDC) and Nathanael doubt (HSLU) deals with the theme of light control. Their design contains two concerted reflectors that are mounted on the facade to optimize the natural illumination of offices. The system is matched digitally on the daily path of the sun. Each reflector has a non-reflective back, with a protective function in case of excessive sun exposure. Depending on the intensity of the sun, the reflectors change their positions to direct extra natural light into the interior when needed. The embedded digital controller navigates the successive tuning of the reflectors in view of the current daylight situation.

Seven more results emerged within the workshop, in which the potential of informing and activation of cladding components were investigated. The results were presented to a professional jury and exhibited within the conference "Facade2015 – COMPUTATIONAL OPTIMISATION" [9, 10] (Fig. 8).

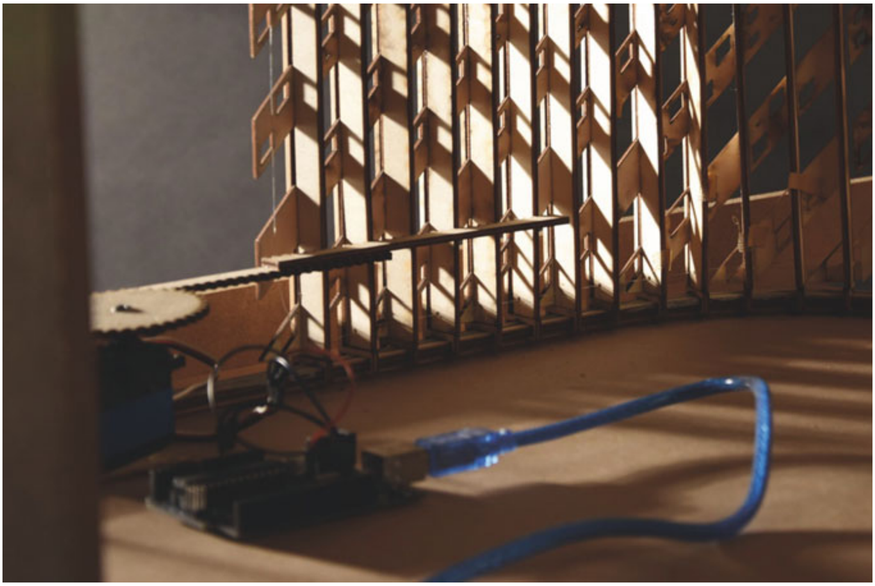

Fig. 8 Result of the project sliding shield by *Julkifli Axel Siswoyo and Vanvithit Bhukanchana*

4 Conclusion

Computer technology offers many new opportunities in architecture. In order to meet the challenge of gaining most benefit from these possibilities, it is essential that experts become qualified, moreover, strategies for the technologies application become researched. Today, new tasks and new responsibilities derive from the extensive digitalization. They are also met in the research of ThinkingSkins by the transfer of digital design strategies to the automation concept for the building's usage phase. The confrontation of students with current research issues lies a great potential for both sides. Students are aware earlier of current issues and future requirements in their field of study while they generate knowledge by the experimental use of new technologies. It is assumed that not every concept of the workshop "façadetronics" can be converted into performance-enhancing components and design principles for façades. The projects show, however, due to available and cost-effective technologies in the field of information technology and electrical engineering, new potentials and possibilities arise to actively cope with the dynamic influences on the façade. The workshops show the extent of the required expertise, necessary for the development of active systems. The need for skills in the development of components and constructions, electrical and control engineering, as well as in information technology and programming shows the necessity of interdisciplinary cooperation in the construction industry. Against this background, the ThinkingSkins workshops contribute as a scenario for multidisciplinary collaboration by bringing together students from different disciplines.

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