IT Driven Architectural Design for All?

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This paper discusses teaching parametric design as a supportive method of introducing design logic. Two case studies have been described, analysed and concluded. The first case study focuses on a workshop based design of a parametric pavilion, which resulted of building 1:1 scale object. The second case study concentrates on the academic compulsory course providing parametric design knowledge based on a particular topic imposed by tutors. In both cases the main purpose was to get students being accustomed to a different way of thinking, to open their minds to new approaches to design process and to demonstrate a connection between programming skills and imagination capabilities. Each of the cases returned valuable guidelines for design studio pedagogy which has also been revealed in this paper.

Keywords: design logic, parametric, design pedagogy

INTRODUCTION

There is no doubt, computers have become main aiding tools for designers nowadays. Fast speeding of computational technologies brings new toolsets for architectural practice. Actually, the IT driven design process is not a novelty and has been gradually adopted in architectural design domain. However, there is a great shift observed lately in the direct influence of programming technologies on design practice. To fully exploit these abilities architects have to obtain new skills and knowledge. This can be done by learning programming or scripting languages which are opening new domains in architectural creativity and "manufacturing the ideas". It has been widely discussed if there is no direct link between a designer’s mind and designing tool, a designer becomes rather a reviewer than a creator (Kepczynska-Walczak 2008). As claimed by Stefan Boeykens and Herman Neuckermans "(...) software can only provide the desired functionality using scripting or programming, to fill in the gaps of the software feature set" (Boeykens and Neuckermans 2009). That possibility of software customization by applying programming abilities is becoming increasingly appreciated. In consequence such situation, on the one hand enforces the universities to make shift in education, but on the other hand opens domains of experimentation and research. There is a great discussion on the scope and methodologies of teaching these emergent technologies since they change the paradigm of design process. The question how to support creative thinking with digital tools still needs further investigation (Kepczynska-Walczak 2014). "However, visual programming approaches that promise to fit the graphical mindset of aspiring architects better are also gaining ground, e.g. Bentley's Generative Component and Grasshopper for McNeel Rhino 3D. The reason for this is reported to be that algorithmical thinking requires a problem-centered approach, while architecture usu-
ally takes a solution-centered strategy" (Wurzer et al. 2011). As the title of the paper suggests there is a question to be answered if the information technologies driven architectural design should be a compulsory part of the curriculum.

**CASE STUDY**

In this chapter two chosen case studies are described, analysed and concluded. Some guidelines for design studio pedagogy is also be revealed. In both cases the main purpose was to get students being accustomed to a different way of thinking, to open their minds to new approaches to design process and to demonstrate a connection between programming skills and imagination capabilities.

**WORKSHOPS - PAVILON P3**

The first case study focuses on a workshop based design of a parametric pavilion. A group of students from Architecture field of study, driven by a need to learn and explore new digital tools more and more commonly used in a worldwide architectural practice, organised a workshop and named it P3 - Process Product Purpose. Its main goal was to learn parametric design methods and use that new knowledge to create a full-scale pavilion not only virtually but also in reality. The workshop was planned as a two weeks long event, including building up the physical 1:1 scale model. However, due to the need to provide more introductory tutorials, and additionally, to a technical delay, it was extended and lasted three weeks. During that time students experienced, in a very intensive and compressed way, a whole design process - from a design concept to realisation on a building site. From the very beginning, a 15 millimetre plywood was chosen as a basic material to construct the physical pavilion. The relatively low price and easiness of tooling were the primary factors in decision making process. Another argument was that the chosen material was highly accessible on the market as a standard construction material. The budget provided for the workshop allowed to buy 78 sheets 2,20 meters long and 1,20 meters wide. It gave over 200 square meters of plywood in total available for students and their imagination. Besides the decision about material the three axis CNC milling machine was chosen for the main manufacturing process. Both a material and a fabrication method were the key constrains imposed on students.

The workshop began with an introduction to parametric tools in the form of an intensive course of Rhinoceros and Grasshopper (see Figure 1). The series of tutorials were planned to cover a wide range of differentiated knowledge of parametric design field including basics of attractors, dynamic relaxation or data managing. During the workshop students' curiosity led to more involving problems such as big data structures, complex geometry dependencies of manufacturing or tagging tasks. It is also worth to mention here that for majority of participants, this workshop was the first opportunity of gaining knowledge about architectural design process driven by algorithms.
Participants were divided into five design teams (Figure 2). Each group was asked to design a vision of the pavilion, concerning a type of material, its limitations, amount, and available manufacturing process. Apart from a pavilion’s architectural form, the high emphasis was placed on the construction and structural issues. During design process, students were asked to omit any traditional joints applied in physical models, such as glue, metal plates or nails. The whole structure was intended to be made of plywood only.

Furthermore, they were encouraged to make mock-ups to evaluate their design and ideas. After a few days of work the midterm presentation was organised, where each group presented their design logic and structural solutions. A few joints prototypes were prepared in CNC milling machine to test their durability and stiffness. The best idea of each group was extracted to become the basis for one common final project.

The main structure of the pavilion was based on a dynamic relaxation algorithm driven by Kangaroo solver for Grasshopper. The Frei Otto studies on tensile (soap bubble) structures and Antonio Gaudi study of inverted gravity logic led students to think of self-supporting structures as a base idea of their projects. A mesh as a starting point for simulation was the result of combination of two algorithms: Voronoi tessellation - to find a general outer shape of a pavilion, and the magnetic field behaviour for a division of the resultant space into triangular mesh (see Figure 4). For both algorithms a starting point for the
A simulation of inverted gravity was run on basic principles of string behaviour. On each node of the mesh an uniformly acting force against gravity was applied. To keep the structure on the ground, designers chose the most characteristic points to be fixed. To enrich the form finding process additional constrains were applied. Creation of overhang entries to the pavilion, on the each site of the structure, required additional structure movement limitations (see Figure 5). Particular nodes in the pavilion were hooked to the ground by strings behaviour to imitate tents strand. The improvement of structural stiffness was achieved by applying supplementary forces acting between plates. That method generate origami effect on the surface of pavilion enhancing it tectonics. Thanks to parametric tools, dynamic relaxation could be running many times with different parameters or additional constrains, which leads to divers outcomes (see Figure 6).

In parallel when part of a team was working on general design of the pavilion, second part of participants worked on 1:1 scale prototype of few adjoints panels, developing the best solution for their connections and joints. Tests on the prototype allowed students to evaluate their ideas and prevented design from a variety of construction errors. When a final de-
With the help of the faculty surveyors and data generated by Grasshopper, the pavilion was precisely marked out on the plot (see Figure 7). As soon as all panels, joints and wedges were cut out, students began pavilion assembly process (see Figure 8). The construction took about five days to complete and was supported by digital instructions prepared by students as a part of the script. Three weeks of intensive work resulted with a structure containing 570 unique panels joined by 1008 connectors mounted by 2016 wedges. This fully digitally designed structure (see Figure 9) became a kind of architectural manifesto for University authorities and other faculty students by showing capabilities of IT tools in contemporary architectural practice (see Figure 10 to 13).

**COMPULSORY COURSE**

A successful result, strong interest and high students attendance at the parametric design workshop confirmed the growing need to introduce a regular course on advanced CAAD tools such as parametric design methods. The first trials to apply these methods were made for the fourth year students of the Bachelor degree. The participants of the course were both, regular enrolled and Erasmus students. The whole course lasted fifteen weeks and was divided into three parts. During the first three weeks students were acquainted with new technologies and approaches in architecture and prepared presentations on chosen topics. A wide-ranging variety of themes was covered, such as an application of 3d printing technology in architecture, BIM process, robotic’s arm aiding fabrication etc. That part aimed to introduce participants to a new environment of computational design, and make aware of recent trends in technologies. Then, subsequent six weeks (the second part of the course) were dedicated to a new software and tools exploration. Students learned about NURBS modelling toolset provided by Rhinoceros3D with additional plugin for Graphic Linear Programing named Grasshopper3D. During this part many examples and practical exercises related to architecture were conducted to make participants familiar with the computational process of designing. It is worth to mention, that none of students had any knowledge or skills in parametric, generative or computational design before. Last part of the course contained a project task. The main assumptions were to design courtyard roofing in our main
To sum up, the aim of the course was to make students accustomed to a different way of thinking, to open their minds to new approaches to design process and to demonstrate that by connecting programming skills with imagination capabilities. The first task - a presentation of up-to-date technologies was intended to be a preface to individual approaches stated in a final design problem. Students presented their research to exchange knowledge and inspire each other with new solutions and opportunities given by a modern technology to reveal how contemporary architectural design might be successfully aid by digital tools.

From the authors’ experience, the learning process of parametric design methods is much more requiring than traditional methods used before. The best results were possible to be achieved during solving individual problems appearing in a project. Focusing on individual projects, students improved their consciousness of parametric design and developed an ability to understand the whole logic behind it. In that scenario, participants were developing their skills faster than through understanding general problems contained in standard tutorials. In our course, tutorials (second part) appeared only to help students rapidly understood a basic workflow of particular tools usage and were limited to minimum. The principal emphasis was put on a final project. A design task for the final project was intended not be complex. Students were encouraged to focus mainly on a building form, its appearance and design logic rather than its functionality. The reason for that was a desire to divert thoughts of students from straightforward design studio problems solving towards the process itself in order to open a potential for enriching a design development. The whole process of achieving a final form of a building or a structure was as important as the final appearance.

**RESULTS**

The case studies represent different approaches in a multifaceted meaning. Nevertheless, some aspects are clearly observable. It is worth stressing here students’ attitudes were highly diversified in both cases. The participation in the workshop was free for all faculty students who were interested in the particular topic. That freedom attracted highly motivated and interested participants. In opposite to the workshop, the compulsory course as a different pedagogical method, gathered all students. The first case definitely demonstrated a high motivation of learning new tools for architectural design. Despite the atmosphere of work with a slightly competing factor, participants inspired and encouraged each other. What is more, the aim of creating and building physical 1:1 scale object occurred a significant incentive. The second case revealed different conclusions, though, it also gave a valuable feedback for teaching parametric design methods. Not all participants performed an ability and developed logical or mathematical way of thinking to fully appreciate parametric design. What is more, during working on their final project, a majority of students was focused only on final result of their work (see Figure 15). The de-
The maturity of students can also influence their design process and the way of thinking. The difference in projects' quality was clearly visible during a final presentation of the compulsory course. Projects delivered by the Erasmus students were much more elaborate (see Figure 16). Their works diverged from the other, by higher sensitivity of design logic and process responsible for a final project. What is interesting, those students were older from the regularly enrolled ones, and additionally they were participants of Master Program in their Alma Mater. This example shown the importance of design maturity of students when Parametric Design course is implemented in a studying program. Two editions of the course show the feeble preparation of bachelor students to complex and demanding designing process such a parametric design. In a contrary to the academic course, the workshop revealed a radically different outcome. All students involved in pavilion development were very proud of the outcome but at the same time they were highly conscious about design process which led them to it.

During the exhibition made after the workshop, the process was the main product exhibited by them. Additionally, neither the academic course nor the workshop assumed the needs of existence of any theoretical part of parametric design. That put our method in contradiction to methods presented by Aguiar and Gonçalves (2015) in their paper. All theoretical problems and questions were answered during computer labs. The usage of graphical, node base programing
application such as Grasshopper3D gave beginner students better visibility what was happening during a script execution. What is more, clear and pleasant graphical user interface did not deter potential users as opposed to the classical written syntax.

CONCLUSIONS

Both case studies enriched authors didactic experience and allowed them to evaluate their teaching methods. As the results of the workshop and compulsory course show, students' predispositions to understand and use parametric designing methods appeared highly diversified. Architecture as a field of study, due to its combination of art and engineering, attracts people with varied skills and aptitudes. Parametric tools require from the user to be more conscious about designing as a process. From teaching point of view, parametric design should be introduced at Master degree program where students' attitude to learn complex tools and her/his design maturity is highly developed. Moreover, it is suggested parametric design classes should be only proposed as elective courses.

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