Digital shift - digital architecture at the Faculty of Architecture SUT in Bratislava

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ABSTRACT: Schools of architecture are becoming research laboratories, which are pushing the boundaries of architectural design. Leading institutions in the current architectural discourse are focusing on topics, such as the interactivity of objects and systems, digital fabrication, virtual and augmented reality. The Faculty of Architecture SUT Bratislava is following these trends in education and it is cooperating with the *rese arch* research organisation. This cooperation consists of lectures, workshops with international attendance and research into non-linear architectural design processes through work with a robotic arm located at FA-SUT. Knowledge gained through this cooperation has been transformed into a variety of digital design strategies that are incorporated into the subject called digital architecture. This article consists of research and examples of Master's degree students' work throughout the duration of this discourse. Use of digital tools and modern technologies plays an important role in differentiation and complementation of this architectural discourse to traditional architectural design processes.

INTRODUCTION

Generative and parametric design is one of the topics pushing boundaries of architecture. Architecture schools, such as AA, Bartlett, SCI-arc, Columbia University or die Angewandte are leading the contemporary discourse. Their research is shifting the discourse technologically and also theoretically, and it is receiving the attention of the architectural community.

The Faculty of Architecture at Slovak University of Technology (SUT) in Bratislava, Slovakia, is following these tendencies and incorporating contemporary topics of the digital discourse into the architectural educational process. The theoretical scope is explained to students in a series of elective courses available for first year Master's degree students, called Introduction to Digital Architecture. Students develop skills to produce projects in line with the contemporary digital discourse. Selected student works have been published in two publications [1][2]. Digital discourse is also incorporated into the educational process through design studio projects and PhD candidates' research. In addition to the regular study programme, the Faculty of Architecture collaborates and supports activities of the independent *rese arch* organisation [3].

TECHNOLOGY IN ARCHITECTURE AND DESIGN

Technology in the Design Process

Digital pencil. Architectural drawing is moving into the digital domain. Computation power is used to simplify and accelerate manual work processes. The workflow, however, is the same as drawing by hand - from concept to repetitive search for the final design.

Automation of processes. Computers have enabled immediate execution of numbers of processes. Thousands of lines may be drawn or modified by one click. Elements may also be concatenated (chained) and, thus, by editing one element, the whole sequence can be changed in a single moment. Various visualisations of mathematical functions, such as Voronoi diagrams or fractals may be also included in this group. BIM software is used for flexible and automated design and preparation of documentation. It is called parametric, but it is used primarily to simplify the workflow. However, it does not bring any change to the conceptual level of architecture. The conventional design process has been changed for a more effective one. Multiplication, aggregation and raster are usually created by identical elements.

Parametric design. Parametric design works with numbers of similar elements, which can have gradients of different properties. Unlike automated design, parametric design can be used for every element-specific decision process. The properties of the elements are determined by parameters that may be defined from the outside or are determined by the element itself.

One of the typical examples of parametric design is a parametric surface subdivision, where data are obtained from analysis or simulation and used as parameters - inputs of the algorithm. The conventional design process of *intention - result* is shifted into *intention - algorithm - parameters - result*. The architect works on a proposed algorithm - a system of relations between inputs and parameters. In the parametric algorithm, there is a moment in the decision-making process for each of the aggregated elements. The result is usually a multitude of similar or slightly different elements.

Emergent design. In the parametric approach, the whole decision making occurs in a moment - a single iteration. An algorithm is used to evaluate the information (parameters) and values are assigned to the elements accordingly. The emergent approach, on the other hand, is iterative in nature. Decision processes are made during each iteration; the system is in constant change. An emergent system consists of a multitude of elements - agents - which have an internal logic or behaviour defined by the algorithm. In each iteration, agents update information and react to the previous iteration result. The integral character of emergent design is a simulation process. By using an emergent approach to design, the resulting design appears after interactions between agents. Assumption of the result is very brief, because the author's impact on the final decisive process is minimal. The author's role is to define the rules, principles and behaviour of elements that should lead to the correct result. Agent systems are the closest to the bottom-up controlled approach. Emergent systems can be observed in nature. Organisms, such as birds, termites or bees use similar decentralised behaviour systems for swarm organisation or when building structures, such as termite mounds or beehives. Building these structures by numbers of organisms (agents) is determined by the internal behaviour of individuals, not by top-down ruled design intention [4].

Fabrication Technologies

Conventional fabrication tools, such as 3D printers, milling machines, cutters or robots are frequently used to create models, prototypes or final products. This approach to fabrication materialises the idea directly and has minimal influence on the design process (concept). The capacity of advanced fabrication technologies, on the other hand, can have a great influence on the design process. There is a unique form of cooperation between the Academy of Performing Arts, the Faculty of Architecture and the *rese arch* independent platform, which includes the KUKA robotic arm that is used for research in architecture and design.

Perception of the World (Shifted by Technologies)

Perception of the world can be manipulated through technology. Optical illusions can be fabricated in the real world through physical installations or in virtual and augmented reality. New augmented reality devices are coming on to the commercial market and they enable a more dynamic and realistic perception of the computer designed world. Augmented reality is enhancing people's vision with virtual content. The existence of this technology could transform the design process itself. Architects could become a true creators of complex virtual worlds, which could have a direct influence on reality [5].

ACTIVITIES AT THE FACULTY OF ARCHITECTURE

Workshops and research activities as collaboration between the Faculty of Architecture, Slovak University of Technology and other institutions:

- *rese arch* LAB with Mateusz Zwierzycki, organised by (with collaboration of FA): *rese arch*, 2014.
- Project leader: Mateusz Zwierzycki.
- Project participants: Ján Pernecký, Štefan Lopušný, Sofia Zourelli, Alexander Ahmad, Jiří Vítek, Ralf Bliem, Konrad Zellner, Tomáš Tholt, Robert Löffler, Adam Klich, Agnieszka Kozłowska, Matej Hoppan and Danica Pišteková.
- Project partners: Ondrej Zachar, Jozef Vaško, Robert Vierlinger, Peter Benkovský, Jozef Pavelka and Ivan Vukdragovic.

This research project was proposed and led by Mateusz Zwierzycki, investigating the opportunities offered by rapid 3D printing methods by merging technologies and materials. Tensile structures have been explored and used widely in the field of architecture. Membranes and eventually additional structures are bearing tensions and pressures. Lately, tensile structures have become a popular topic for the digital approach. It is also possible to create simulations of complex compound minimal surfaces by applying the properties of membrane structures. Simulations are taking properties of materials into consideration and thus are very precise - transition of data from the digital domain into the physical world is reliable. This transition was very important for implementing the project.

New opportunities are brought forward by using the KUKA robot in the process. The ability to follow double-curved surfaces along with the option to mount an effector was the basic precondition of the project. A 3D printing effector is not used to create form in a convenient way, layer after layer. In this case, printed plastic is used as a reinforcement structure - it is extruded onto pre-stretched fabric. After the extrusion process, the fabric is stabilised in the form. Depending on the setup of the system, it was possible to get numerical results and to investigate various concepts and approaches as modular structures, statics simulations used for finding the form of printed elements, layering, structural patterns or folding (Figure 1).

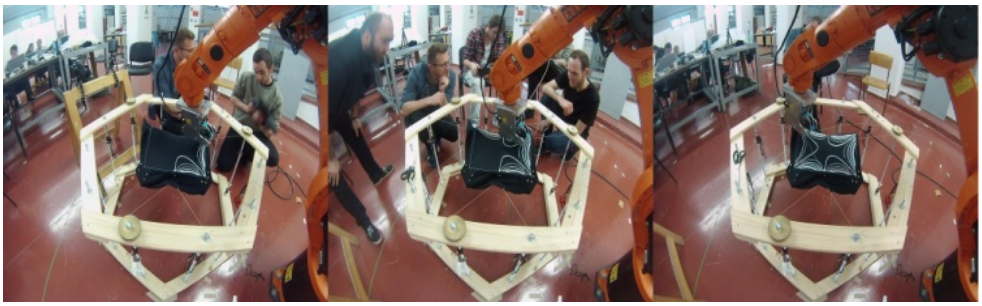

Figure 1: *rese arch* LAB with M. Zwierzycki - Fabrication process, photo by T. Tholt. Iterative Interpretations Summer School, organised by (with collaboration of FA): 3D Dreaming, *rese arch*, 2104. Workshop tutors: M. Pryor, M. Zwierzycki and J. Pernecký.

The aim of the educational workshop was to provide an introduction to the iterative approach. The traditional parametric workflow of the Grasshopper plugin for Rhino 3D was enhanced through use of the Anemone plugin created by Mateusz Zwierzycki. Using an iterative approach made it possible to work with more complex phenomena, such as growths, simulations of processes, applying mathematical phenomena, such as cellular automata and fractals into the design process. Various generative processes used in the workshop culminated with the introduction to the emergent paradigm and simulations of flock behaviour (Figure 2).

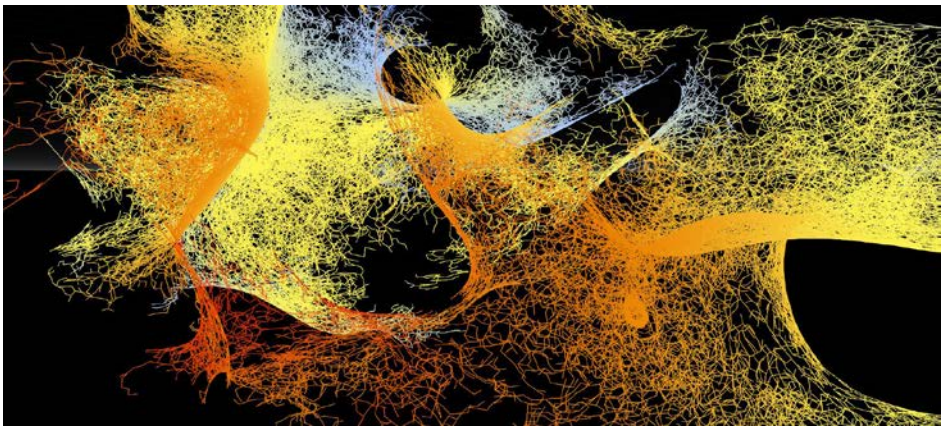

Figure 2: Iterative Interpretations Summer School - Perlin Noise Growth. Workshop tutors: M. Pryor, M. Zwierzycki and J. Pernecký. Visualisation: T. Tholt.

– Spring Species Workshop, organised by (with collaboration of FA): 3D Dreaming and *rese arch*, 2014.
– Workshop tutors: Andrei Paudre and Alex Ahmad.

The workshop topic was to introduce advanced physics simulations into the design process. Tensile structures have been a topic of research in architecture for a long time. Digital tools allow the designer to investigate the behaviour of structures in physical simulations. Complex structures may be optimised for the best structural properties and used in architecture in the design process (Figure 3).

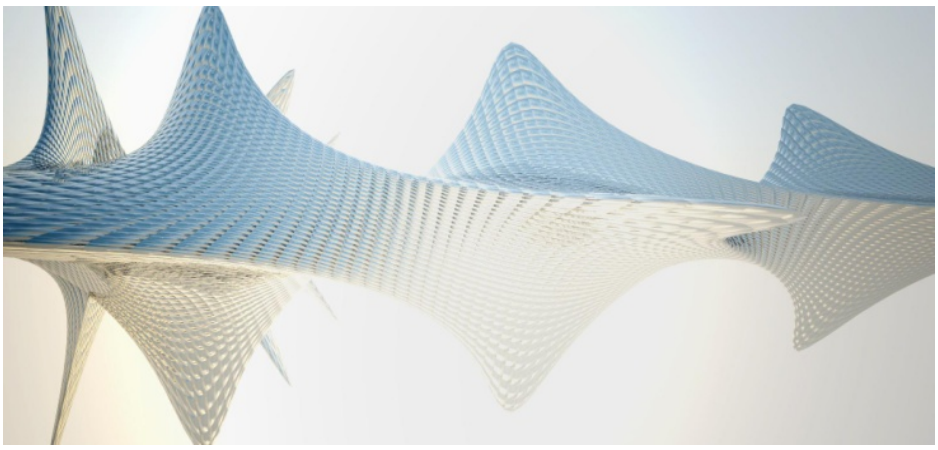

Figure 3: Spring Species Workshop - Minimal Surface Simulation. Workshop tutors: A. Paudre and A. Ahmad. Visualisation: A. Paudre and A. Ahmad.

- EcoType Winter School. Organised by (with collaboration of FA): 3D Dreaming and *rese arch*, 2014.
- Workshop tutors: Iker Mugarra Flores, Aldo Sollazo, Jelica Jovanovic and Dragana Petrovic.

The workshop aimed to introduce a holistic approach into the conceptual process. The main topics were digital environmental simulations and the genetic algorithm optimisation of the form determined by a multitude of parameters. New design opportunities come from software able to gather and process complex data. Shifting from a linear process, the result of such approach is a structure created as a reaction to associative simulations of the relations between tectonics and the environment (Figure 4) [6].

Figure 4: EcoType Winter School - final design group project. Workshop tutors: I.M. Flores, A. Sollazo, J. Jovanovic, and D. Petrovic. Project authors: M. Lipková, M. Dubiš, A. Leitmannová, Š. Lopušný and J. Vítek.

Robert Neumayr lecture *Parametric Cookbook*, organised by Robert Loffler and Tomáš Tholt, 2014.

Robert Neumayr is an assistant in the Hadid studio at the University of Applied Arts in Vienna. In 2014, he gave a lecture called *Parametric Cookbook*. This lecture was an introduction to the discourse of parametric architecture. The lecture included examples of students' work, the theory behind parametric architecture and possible applications of parametric design in architecture (Figure 9 and 10).

Pedagogical activities conducted directly at the Faculty of Architecture:

- Digital Architecture Course.
- Tutors in 2014/2015: Vladimír Šimkovič, Robert Loffler, Tomáš Tholt, Martin Uhrík and Ramón Velazquez.

In the first semester of the course, students are taught the necessary skillset of the software most frequently used in digital design and research. Along with the software basics, students have a chance to attend lectures and discussions about the contemporary discourse in architecture. During the second semester, theoretical and practical knowledge is applied in a small conceptual design studio. Most of the projects are fabricated, presented and displayed at faculty events (Figure 5).

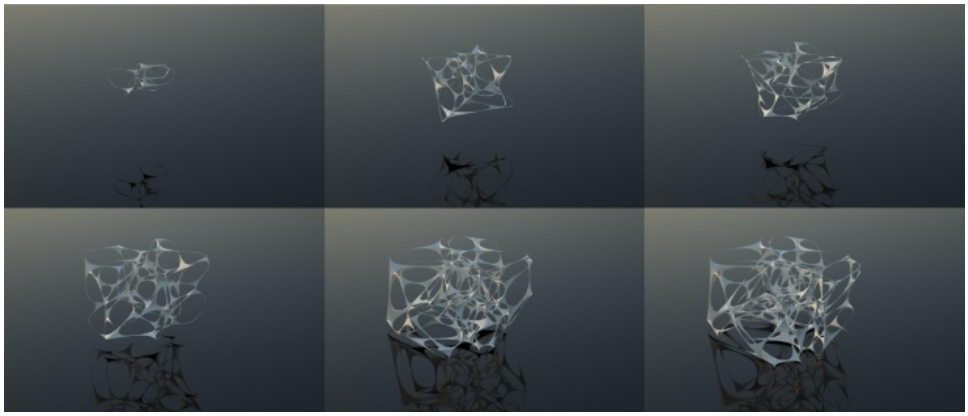

Figure 5: E. Hrivikova - growing self-organising structure. Project tutor: J. Pernecký (2014).

Design Studio

The complete design studio project is based on comprehensive use of theoretical and practical knowledge of topics related to digital discourse. The full application of digital concepts to the field of architecture is important. These projects are mostly appreciated by the semesters' final critics. (Figures 6 and 7).

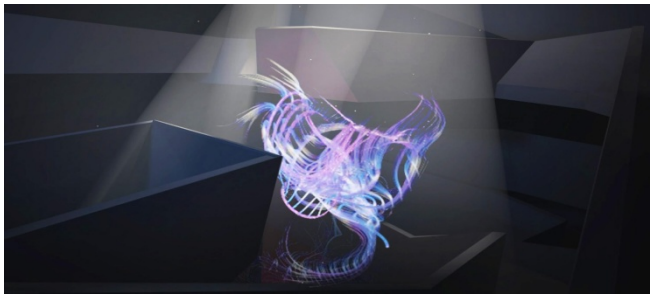

Figure 6: M. Hajduk and R. Hajtmánek - Design studio project. Project tutors: V. Šimkovič, R. Loffler and T. Tholt (2015).

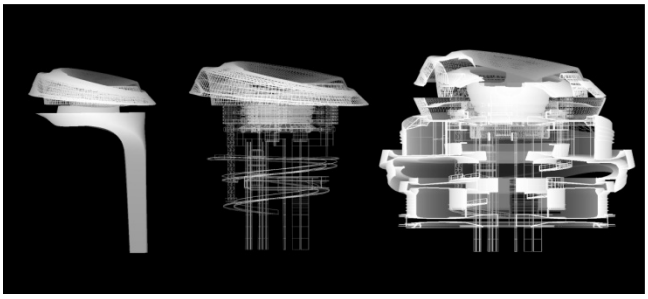

Figure 7: L. Petráková - Design studio project. Project tutor: V. Šimkovič (2015).

PhD Candidate Research

Research activities are undertaken by PhD candidates on the topic of emergent design and fabrication. Coordination of pedagogical and research activities in the digital discourse and development of topics for students supporting the discourse are important parts of the work. (Figure 8 and 9).

Figure 8: T. Tholt - Double layered growth and swarm behaviour simulation study (2015).

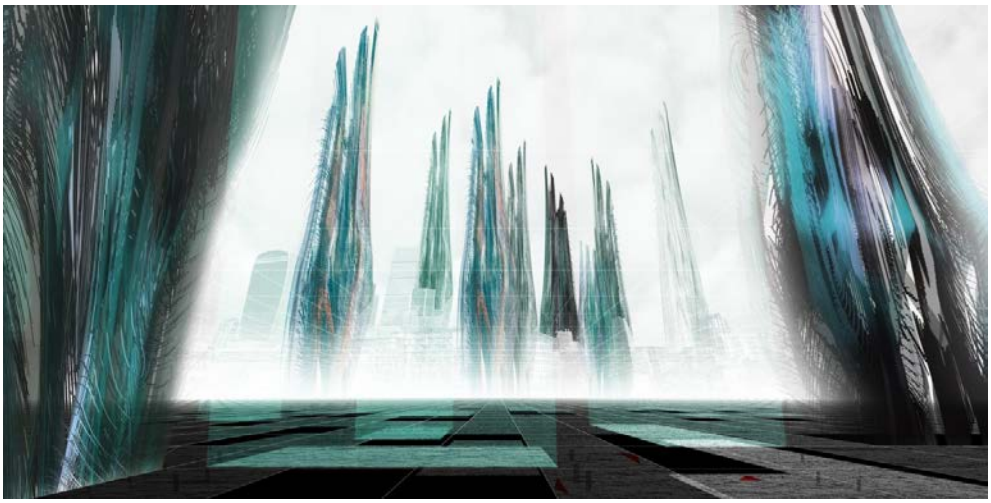

Figure 9: R. Loffler and M. Lucký - Augmented city, Real Unreal - eVolo competition entry (2015).

CONCLUSIONS

The digital approach to architecture - algorithmic, parametric, emergent modelling processes - have the ability to process complex influences and reflect them in the formal and/or programmatic structure of architecture and design. These tools have the capacity to reflect various structural, environmental and social needs, simulate them and work with them at a conceptual level. It is possible to observe a wide spectrum of approaches to digital technology in architecture, from technologically driven morphogenesis as a result of scientific research, to semiological reflections of meanings in the new forms of architecture.

Most of the students' projects at the Faculty of Architecture (but worldwide as well) are somewhere in between these two approaches. There is a tendency to use cutting edge design tools; thereby, surpassing the traditional methods. Incorporating these tools into the process of education is vital, because the capacity to change architecture occurs not only in the level of efficiency and speed of design process but, even more importantly, in new topics in architecture. Analytical and conceptual thinking is necessary in order to apply the digital paradigm in architectural design. This approach is usually closely connected with research activities. Application of such processes in architecture design has an extensive impact both in the scope of the digital paradigm, and in *conventional* architecture. That might be considered the greatest impact on the teaching quality, (Figure 10) [1][2][7].

Figure 10: M. Štrbíková - Conventional approach to architectural design. Design studio project. Project tutor: V. Šimkovič (2015).

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