Computation As Design Logic Indicator

The Expo Project Experiment

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The city of Lodz is bidding for hosting International EXPO in 2022. The proposed theme is "City Re:Invented". The paper presents the EXPO project experiment conducted at Lodz University of Technology in cooperation with Lodz City Council. The idea was to prepare design proposals for promotional purposes, first in the form of computer visualisations, then as physical scale mock-ups produced in a digital fabrication laboratory. It is planned that the best solutions would be adopted and built in 1:1 scale if Lodz received a nomination. The results of the project are illustrated in the paper by selected examples. The main aim of this study is to examine computational thinking as a design medium. The paper presents background studies in this regard. It also looks into the approach to articulate digital fabrication and robotics as not merely the methods of delivery of a final product but their role in a design process. It deliberates pros and cons of computational design and its influence on creativity. It concludes with a statement that computation may help to construct, reveal, enhance and develop logic in a creation process.

Keywords: computational design, parametric modelling, digital fabrication, creativity, EXPO

INTRODUCTION

The city of Lodz is bidding for hosting International EXPO in 2022. It has been already involving intensive planning and promotional activities at the local, national and international levels. The proposed theme for EXPO is "City Re:Invented". The main idea is to revitalise the city downtowns and bring the event to the city centre which is opposite to the recent tendencies to organise such events in the city outskirts. What is more, since expos are expected to act as showrooms for new trends and technological solutions, hosting EXPO becomes even more challenging in numerous aspects. Therefore, Lodz University of Technology, Department of Digital Technologies in Architecture and Urban Planning undertook cooperation with the City Council and the EXPO Team. The idea was to prepare design proposals for promotional purposes, first in the form of computer visualisations, then as physical scale mock-ups produced in a digital fabrication laboratory. It was planned that the best solutions would be adopted and built in 1:1 scale if Lodz received a nomination.
The EXPO project experiment had much more complex role to play since it was expected that the process of developing ideas would gain strength and logic through the application of parametric design tools. Acquiring skills in advanced computer techniques was a crucial element of fulfilling the course learning outcomes. Thus, the approach to articulate computational thinking in a design process was formulated as the main assumption. In consequence, a discussion on the outcomes of the design task addresses the topic of computational design in education. The paper also looks into computational workflow from form-finding at the early stage of design, through modelling and optimising to digital fabrication processes.

BACKGROUND
For the purpose of this study two background topics need to be elaborated on. The first one is connected with the shift in the paradigm of Computer Aided Design, while the second issue brings more details about the plans for EXPO 2022 in Lodz.

Computational design
Dynamically developing advancements in information technologies which influence architectural domain have been observed for decades now. Although not all of them have been implemented or adopted in everyday practice, they are a stimulus for further innovations. The pace of change may be well illustrated by the following statement: “The current transition from Computer Aided Design (CAD) to Computational Design in architecture represents a profound shift in design thinking and methods. Representation is being replaced by simulation, and the crafting of objects is moving towards the generation of integrated systems through designer-authored computational processes” (Menges and Ahlquist 2011). Complementary, research and experiments in digital fabrication techniques bring novel opportunities for IT driven design process. However, it is still observed that “with the developments in digital fabrication, the production and assembly of complex forms has been compromised by the constraints of selected fabrication techniques” (Erdine, Elif and Kallegias 2016). Another constrain which may aid the background study is that “at this moment in history (...) technical challenges restrict design thinking, the creative process, and also visions of 3D printing possibilities” (Turunen 2016).

Referring to Sousa, Varela and Martins (2015), the last decade assisted to emergence of robotic applications in architecture, and popularity of robots in this domain is growing. Braumann and Brell-Cokcan (2011) presented a user-centred research where the objective was to enable a wide range of architects in the use of robots with a similar ease of use compared to conventional CNC-machines and an intuitive approach towards mass customization.

Actually, the world’s first architectural robotic laboratory for non-standard assembly processes was erected at ETH Zurich. The pioneering work of Gramazio and Kohler (2008) should be mentioned here. Robotic technologies were used to bridge design and construction in architecture. The technology was tested on bricks as the basic modules. As the authors revealed, “bricks, being the primary module for construction (...) allowed us to concentrate on the design of completely programmed walls (...) In using an additive digital fabrication process, a novel architectural product of the kind “brick wall” emerged, which could not have been conceived or fabricated manually” (Bonswetch et al. 2006).

However, after more than decade and despite the continuity of further development of applications robots still remain “an expensive and uncommon technology in building construction, which, furthermore, require several other automation devices to assure a flexible and autonomous functioning (e.g., a system for feeding the bricks to the robot, a tool for laying the mortar or glue on the bricks, or sensors to monitor the correct geometric evolution of the built structure)” (Sousa, Varela and Martins 2015). It might be concluded that “while digital technologies have freed architectural innovation for star-architects while producing several layers of intricate morphological complexities, small and medium architectural firms deal with other levels of day-to-day challenges,
dependent of the architect’s level of expertise and size of firm” (Stals, Jancart and Elsen 2016).

The state of the art in computational design domain would not be complete without mentioning coding as a new medium for architects. According to Davis and Peeters (2013), coding has become increasingly accessible as a design medium in architecture and design. Furthermore, design software is more and more extended and customised through the development of scripting interfaces, add-ons, plugins, libraries, integrated development environments and programming languages. On the one hand, it is believed that designing “through writing custom code has shifted from being practiced by a handful of academics and pioneers to a broad emerging culture of coding in architecture and design” (Burry 2011). On the other hand, the tendency is not so obvious when it comes to small and medium firms since they actually constitute the majority of architectural practices (Stals, Jancart and Elsen 2016). Another author argues that coding is not a mere tool for designing but a particular design medium, with its own affordances and resistances. “Using code as a design medium provides a specific form of feedback, it influences the design process and its outcomes. Code is a technological and conceptual support for design thinking” (Cannaerts 2016). Lorenz and Wurzer (2016) go further and point out problem thinking is still underrepresented in architectural practice. Recently they conducted a didactic experiment which purpose was to emphasize problem thinking over solution generation. So, students were expected to express their designs in terms of code. However, Lawson experiment proved that while scientists have a problem-focused strategy architects perform a solution-focused strategy (Lawson 2005). There is no doubt, while considering computational methods in architecture, visual results depend mainly on cognition of algorithmic design and programming skills. (Kepczynska-Walczak 2008).

**Bid for the EXPO in Lodz**

The World’s fairs have long-standing tradition since the very first event organised in London in 1851. The exhibitions promoted progress in science and technology. In the 19th century this meant industrialisation while themes of recently organised fairs shifted towards social and environmental issues. The next International EXPO is expected to be organised either in 2022 or 2023. Three cities are bidding for hosting this event. One of them is Lodz, the third largest city in Poland.

The proposed topic of the exhibition is “City Re:Invented”. This idea is based on a local experience. Lodz was once major textile production centre. Since the early 1990s local authorities have had to deal with issues related to industrial decline. This requires - apart from solving numerous problems of versatile nature - to answer a question: what should be the city about, now and in the future? This is a universal challenge, since - as recent studies indicate - more than a half of the world population lives in urban areas, and virtually all countries of the world are becoming increasingly urbanized [1]. The current figure (54.5 per cent) will increase to 66 per cent by 2050, which means that one third of people will live in urban areas then [United Nations, 2014]. What is more, it is expected that by 2030 some 60 per cent of people will live in cities with at least half a million inhabitants [United Nations, 2016]. In the light of the above, there is an urgent need for the improvement of the quality of life in the cities. Therefore, urban regeneration becomes a global challenge and a prerequisite for further development of agglomerations around the world (Monclus 2006).

Unprecedented revitalisation process has been already launched in Lodz. The program will cover a large part of the inner city. The figures are impressive: the designated urban regeneration zone embraces some 4500 acres with 21,000 buildings inhabited by more than 150,000 citizens. The development strategy of the city of Lodz aims at higher quality of life, inclusive and varied public spaces, social cohesion, creative atmosphere, well-kept heritage, living culture and more inhabitants in a city centre.

All recently organised World’s fairs were situated at the city outskirts. Such location would be in con-
tradiction to the proposed topic of the EXPO in Lodz. Therefore, local authorities designated an area next to the city centre, where the exhibition could be organised. In other words, the EXPO would return to the city, as it was in the 19th century. On the one hand, the location is a great asset of Lodz application, while on the other hand, this is a great challenge not only in terms of managing a successful integration of the EXPO with the city, but also of achieving a synergistic and sustained city-creative effect. Therefore, the bidding for Expo involves not only intensive planning but also promotional activities.

PROJECTS FOR THE EXPO

The EXPO project was conducted at the Department of Digital Technologies in Architecture and Urban Planning. It was done within the frameworks of Computer Methods In Architecture course at the undergraduate studies. The aim of the course is to introduce the latest tendencies and technologies of computer aided design (e.g.: parametrisation, generative architecture, generative methods of design, computer aided architectural survey tools, 3D scanning, point clouds, photogrammetry, rapid prototyping, reverse engineering, VR, AR). Tutorials are in English since they are addressed not only to Polish but also to foreign students. This is one-semester course, which means that students had some 15 weeks to develop their ideas, transform them into projects and finally prepared scaled models with the use of digital fabrication tools. It is necessary to add that there are 30h and 3ECTS assigned to the course altogether.

It was expected design proposals would reflect computational thinking and selected projects would be fabricated digitally. Since gaining skills in advanced computer techniques was a crucial element of fulfilling the course learning outcomes, students were asked to use computer methods from the very beginning, in particular algorithmic and parametric tools to find and follow logic in design process. In all cases the design geometry was modelled in McNeel Rhinoceros and then Grasshopper plugin played a key role in parametric explorations. It is necessary to stress here, participants were not familiar either with parametric tools or computational problem thinking.

There were thirty six students enrolled to the course working out their individual design ideas in the first phase. Then, eleven most promising concepts were chosen for further development. The evaluation was made after students’ midterm presentations with the participation of the City Council representative. Thus, the second phase of the project based on working in groups. The motives of eleven final design proposals were as follows: “Lodz Genius Loci”, “Re:Connection”, “Urban Tap”, “Spool Pavilion”, “Folk Interactive Bench”, “Back To Childhood”, “Brick Reinvented”, “Public Toilet Unit”, “Bright Boat”, “Gift Box Brick”, “Bike Bell”. The final presentation of project results took place in January 2017.

The Faculty authorities as well as City authorities were invited to evaluate the outcomes. It developed into a fruitful discussion and plans for further co-operation.
To demonstrate outcomes and illustrate computational design processes selected projects will be described and discussed.

**Brick Reinvented**
An inspiration for this project was twofold: the softness of fabric, reflecting Lodz industrial past power in textile production, and brick - a building material typical for Lodz factories, chimneys and workers’ houses. Thus, heritage values played a prominent role from the first phase of the design. Since the project was expected to be technologically driven, students searched for the best solutions to turn their first ideas into physical model. They started from modelling a brick module in 3D digital environment - a basic component, allowing for testing complex compositions. Then, the actual purpose for a composition was defined. So, it was decided to propose a unique bench which could be constructed ideally with the help of a robot. As students were asked to make some studies on technology, they found the idea of “programmed wall” (described in the “Background” section) which inspired their vision. There is no doubt, building such an object up for EXPO would attract visitors and citizens since such event is not a commonplace (yet). However, for the purpose of the final presentation a 3D printed mock-up was prepared what required different processing of the digital model, and affected its final appearance. It is well illustrated in figure 1.

The author of the initial concept of this project was Maria Kierzkowska-Kłys. She was supported by Piotr Mrówczyński, Alicja Zbrojewska and Xuejiao Xu at the stage of its development and fabrication.

**Folk Interactive Bench**
Music became the main motive for this project reflecting the fact that Alexander Tansman and Arthur Rubinstein were connected with Lodz. The concept was to educate citizens and visitors by allowing them to interact with music. A design (geometry and colour concept) itself took inspiration from a special paper-cut flower pattern, characteristic for traditional folk culture from the Lowicz region in the province of Lodz. Such interactive bench would attract people and improve the quality of revitalised downtown. The crucial aspect in this project was the question how to transform two-dimensional floral forms into urban furniture. Looking for computational logic students decided on triangulation of initial geometrical form to build a 3D structure from that (figure 2).

The author of the initial design idea was Karolina Dróżdż. At the second phase of the project a team was formed by three more students: Katarzyna Jackiewicz, Martyna Jankowska, Yiming Gui.

**Spool Pavilion**
The title of the project refers to the city industrial past. Moreover, it is embedded in the shape of designed pavilion. A wooden spool with the thread wrapped around makes a light structure which can be used as a pavilion to sit and rest inside or walk through. In the first model threads were composed in a way to resemble real spool, but finally, due to modifications required by construction and transparency of the top part, the object seems to be rather inspired by a spool than a copy of it (figure 3).
There were four students involved in this project, namely: Joanna Sobczak, Paulina Dobroszek, Sylwia Pietrzak and Paula Popczak.

**Lodz Genius Loci**

Students proposed an installation for a public space that would tell a story of the city on specially designed panels. A unique history of Lodz, its dynamic growth, prosperity, then collapse, and finally the rise towards revitalisation and EXPO 2022, has become the main motive for the project. A colour code was taken from the Lodz EXPO logo. This light semi-transparent structure can serve as a meeting point, offering not only a historical path to follow or a journey through time but also a shadow in a sunny day and creative space for children. What is more, students made proposals for other cities in Poland to place this installation in a position it would point geographically towards Lodz and EXPO 2022. In the case of this project the transformation from intangible to tangible, from historical facts into geometrical form, was the principal challenge. As the first panel is a metaphor of small weaver houses, and the last one is a symbol of EXPO, whereas middle panels show the growth of Lodz in 19th century and collapse of textile industry in the 1990s, the crucial task was to elaborate on the geometry of metaphorical transformation (figure 4).

The author of the initial concept of this project was Lucia Barancokova, supported by Alvaro Soriano Lazaro, Ongan Caglar at the stage of its development and fabrication.

**Re:Connection**

A task undertaken in this project was to make a connection between Piotrkowska Street, a principal axis of historical area in Lodz, and New Centre of Lodz where the new main railway station has been opened recently and where the EXPO 2022 is planned. Therefore, a neglected empty plot at the corner of Sienkiewicza Street and Traugutta Street, being half-way of the pedestrian route between the...
railway station and Piotrkowska Street, was chosen for the project. The proposal focused on revitalisation of the area to make it attractive for all ages. The individual arrangement of modular elements, enhanced by the city of Lodz logo colour code was proposed. The cubical forms might also resemble Avant-garde Modern design of the 1920s which was important for sculptures and paintings of local artists, being themselves icons of Polish art of the period. Designed modules allow to arrange the area in various ways. Simulations and different scenarios were tested. Due to this flexibility the system of elements may be adopted in many places in the city (figure 5).

The idea of this project was proposed by Miriama Butkova. She was supported by Baris Kavarooglu at the stage of its development and fabrication.

DISCUSSION AND CONCLUSIONS
The cooperation between Lodz University of Technology and Lodz City Council strongly supported the promotion of hosting Expo in 2022. The project results revealed the complexity of the topic on the one hand, and the creativity of students on the other hand. The span of the first set of ideas was immense: from small scale products to urban space improvements. Eleven projects chosen for the second phase development were also manifold.

The key value for students was to open minds to creativity, yet reflecting genius loci, local heritage and revitalisation aspects, and, on the top of that - due to the nature of the course - employing parametric design and digital fabrication as a compulsory toolset for the task. It is worth noting here, participants did not have a prior experience either in parametric design tools or digital fabrication, so this part of the course was a challenge itself. There is no doubt, the course was experimental in nature. For the purpose of fulfilling the course construct, graphic coding and visual parametric modelling in Grasshopper was introduced and became a design medium for elaboration on EXPO projects.

The experimental nature of the task involving a variety of digital technologies allowed to test students abilities in IT driven design logic. It must be stressed that neither robots nor 3D printers are the common place in architectural offices in Poland. Both, the infrastructure and software, are too expensive and by that not affordable for small and medium architectural practices. What is more, since it would require specialised staff and time investment to learn and keep up with the latest technology, it seems smaller firms are not interested in such development. Though, it does not mean they do not use digital tools, they just choose the most necessary ones to
deal with design process. This situation is not local, viz. Polish, and it was well described by Stals, Jancart and Elsen (see “Background” section for more details).

Another problem is attitude polarization and resistance to paradigm shift. Architects, especially those with more than twenty years of practice, are the main opponents of technological innovations assumed as disruptive innovations. Thus the EXPO project gave participants the unprecedented possibility to experiment, research, learn and open minds to computational design as an alternative at least if not the future design methods. However, the problematics of computational design requires more attention.

It is observed that predefined working environment has an evident impact on a creative process. What is more, the creative process is limited or even blocked when necessary computational skills are missing. That is why such phenomena as dichotomy, dualism or hybridisation are associated with an early phase of design (Kepczynska-Walczak 2014). It is worth noting that students who start a design task by opening a certain program need much more time to come up with an idea, since they are limited not only by their imagination but also by chosen software capabilities.

Despite the EXPO project was predefined in terms of digital tools to be used from the early design phase towards fabrication process, the methodology adopted was to learn by experience. (cf Kepczynska-Walczak 2013). In this regard, the author would agree with Lorenz and Wurzer (2016) who observed that from the very beginning of the design process students tend to have an almost finished picture - or at least a sketch - of their design ready in mind. Even this picture may change during the process of analysis and/or design, an interim result is present. Furthermore, when concerning problem thinking over solution generation it turns out that in most cases students still have certain results in mind. Sometimes the algorithm is even developed to fit this idea.

To sum up, computation may help to construct, reveal, enhance and develop logic in a creation process, but first technical competences are essential to be acquired.

Figure 5
Re:Connection - a design proposal for EXPO 2022 in Lodz
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