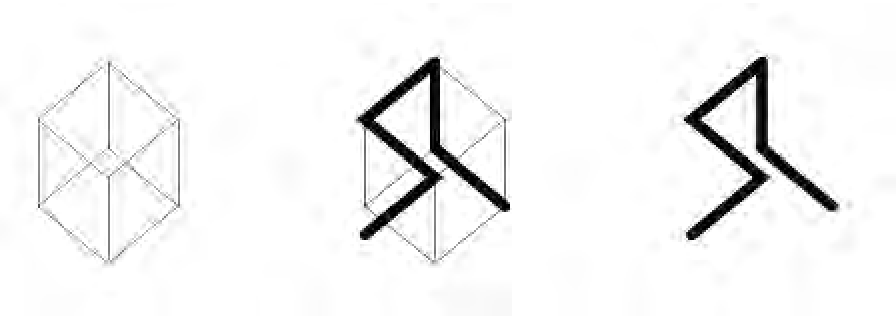

SHAPES OF LOGIC

EVERYTHING THAT SURROUNDS US CAN BE DESCRIBED

Oficyna Wydawnicza Politechniki Wrocławskiej
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My interest is in the future because
I am going to spend the rest of my life there.

Charles Ketterling

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INTRODUCTION

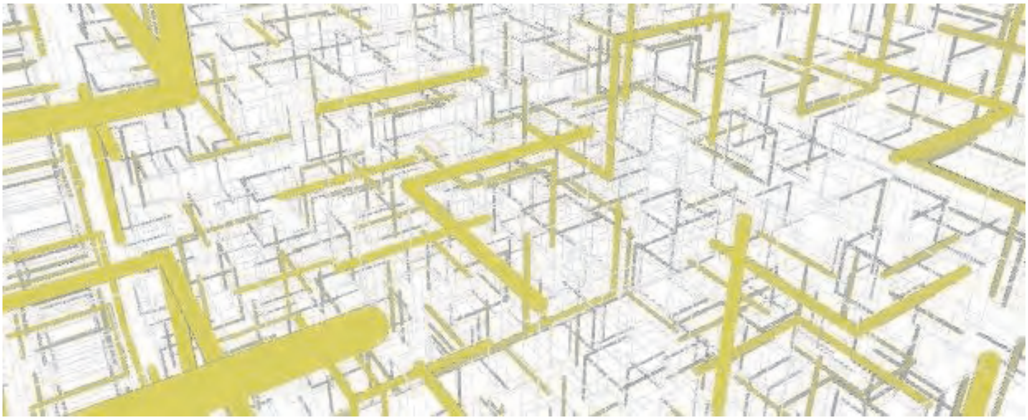
The idea for the book you are holding in your hands was born during the international conference of parametric design *Shapes of Logic*. It was probably one of the earliest (if not the first) Polish conference addressing the subject of computation in design and architecture.

The abundance of exchanged knowledge influenced us to create this monography encompassing most of the topics on modern architecture. We decided to group the articles in 4 chapters: *Methodologies, Evolutionary Algorithms, Fabrication and Urban Structures.* They gradually introduce a reader to the world of parametric architecture, morphogenesis and their practical applications.

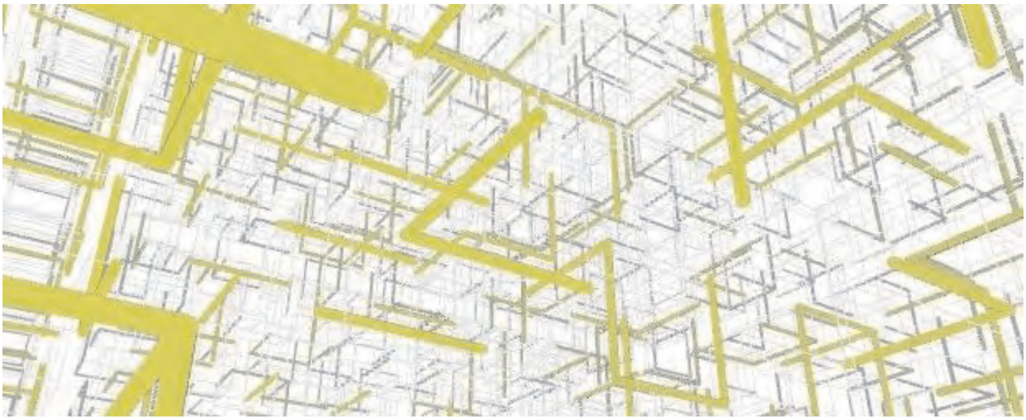
We would like to specifically thank the polish distributor of Graphisoft products *WSC Witold Szymanik i S-ka Sp. z o.o.,* for the support which let this book see the sunlight.

We wish you all the best and hereby invite you to explore this short book,

Shapes of Logic Team



METHODOLOGIES



WHERE IS THE LIMIT OF PARAMETRIC DESIGN?

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Dynamic development of parametric design method in recent decades caused a fact of associated parameter in architecture design with advanced, nurbs geometry objects. Participation of computer programming language into contemporary tools of design seems to define this method. However the parameter has been accompanied architects' from the begging. In ancient times, building aesthetic, especially of public buildings, had been identical with composition which had been created by proportion. During centuries proportions has been changed. They were adapted to current life standards as well as current esthetical values. Composition based on parameters has penetrated into other arts, first of all into painting. Parametric connection between elements often where based on complex mathematical relations. Those parameters very rarely were designated by economy aspects of building development. Also the same approach seems to be represented by the most spectacular buildings of recent years. Characterized by effective look and forgotten about financial aspect, they refer to splendour of the greatest buildings of previous centuries.

So, why most of us claim that the parametric design is an achievement of recent decades? What parameters currently determinate architectural style? What parameters are being used nowadays? Which one has been excluded and which one weren't used in the Middle Age for e.g.? Is the role of architects during the contemporary design process less important than in the past? Or maybe current conditions force them to think about valuate of architectural design? Where are the borders of parametric design? In the fact of determining completely the design process by computers' tools is there anybody who designs in the different way nowadays? Has ever anybody designed differently? Only understanding of Genesis of parameters participating into architectural design allows for constructive criticism of this methods in its present form. Let us answer the question about the role of architects in the contemporary design process.

INTRODUCTION

Number of applications offered by parametric design techniques allows to have the impression that it is a crucial moment in history. Application's compatibility with wide set of not related areas opens wide interdisciplinary possibilities. It can be easily seen by its expansive nature during the last decades. The dynamic development of parametric design techniques makes the theorists of architecture lag behind their current state. In this paper I will try to examine the most important issues associated with modern architectural design.

PARAMETRIC DESIGN AS A SUBSTITUTE FOR PENCIL AND PAPER

The excitement about the possibilities which parametric design provides caused the dynamic development of the practical aspect of architectural modelling. However, the theoretical aspects became neglected. That is why most people mistake the applications of parametric design for its definition. These definitions are mostly based on the functions designers use during the modelling process. They are often inaccurate and mi leading for people that are just beginning their work with parameters. A few of them are listed below (staring with the most poetic one):

"Please, feel invited to attend the class on the foundations of parametric modelling of architectural ideas in a virtual space and on the application of innovations in architectural design."

The above quote is an invitation issued by the administration of the Faculty of Architecture at Krakow University of Technology. In the more detailed description of the course one can find the following sentence:

"(…) The goal of the course: being able to use Building Information Modelling [BIM]. It is a process in which the final form of a design is the iteration of a piece of geometric information placed in a "tree" which possesses hierarchic relations between its elements." [1]

The BIM technology is based on ready-made elements included in the software. These elements are indeed strictly related: the change of the width of one sort of a window results in an automatic correction of all the windows in a model. However, using the pre-made elements is a limitation to a design process. Dealing with parametric modelling designers uses only geometrical elements such as a point, a line and a surface which may create any desired object. What is more, in cause of generative or evolutionary design, it is the line of program code which draws the geometrical elements. These tools give much bigger latitude than pencil and paper.

A different approach to this matter is presented by the authors of the article published on Polish architectural website bryla.pl. [2] In this case, the expression "parametric design" was replaced by „parametric modelling". The distinction between design and modelling is a reasonable step. However focus by the author of the article on a suitable choice of words in the definition, which we find below can be surprising:

"(…) one may say that "parametric modelling" makes practical use of modern information technology and computer science to the benefit of architectural, industrial and interior design etc."

In this definition author does not even mention the most important characteristics of parametric design, distinguishing it among other CAD technologies, which is the creation of a geometry throughout the process. However, he did mention information technology which is the key element to estimate the value and the sort of parameters the geometry will be based on. Since nowadays we are dealing with a big amount of data, it is crucial to be able to convert, analyse and connect it by algorithms and parameters in an efficient way.

The problem of information is brought up in the following definition:

"(…) Buildings designed in such a way are created not by the modification of a solid's shape but the parameters defining them thanks to correlated equations. (…) The essence of the parametric architecture understood in such a way is, therefore, the focus on the information which models a building but not on a form itself since the form is only the outcome of entered data." [3]

The above description of the parametric design is the comprehensive one as it touches both technical aspect of modelling and the theory of the process.

A PARAMETER IN THE MODER ARCHITECTURE

The development of the CAD (Computer Aided Design) tools has liberated designers from the limitations imposed by the difficulty of drawing complicated geometries in a traditional way. This event coincided with civil engineering and technological booms and the transformation of NC to CNC technologies[1] (and

[1] Numerical Control and Computer Numerical Control.

the introduction of CAM technology[2]). It has provided designers with a whole variety of possibilities. The moment tools and technology were no longer a problem, the designers started to search for inspirations in many new fields. New trends emerged. Some of them are presented below.[3]

ORGANIC ARCHITECTURE

The term “organic architecture” was first mentioned in the beginning of 20th century. Beside the American architect Louis Sullivan and the German designer Hugo Haring, its major forerunner was Frank Lloyd Wright. He saw organic architecture as the cohesion of architecture with a surrounding natural environment. This cohesion can be achieved in many different ways starting with the introduction of floral ornaments and the integration with a nature (e.g. the introduction of water flowing through the interior of Falling water by Wright). [4] Organic design, therefore, does not characterize the principles a geometric model ought to obey but determines a function and an object’s character.

BIONIC ARCHITECTURE

Bionics became popular in the second half of 20th century. Being an interdisciplinary subject, it searches for solutions to various problems in nature and applies them to robotics, electronics and control engineering. Despite the fact that its name originates from the word “bios” and “electronics” it was quickly adopted to other fields, such as architecture, aerodynamics and constructions. The word “biomimetics” is also in common use. It derives from Greek “mimesis” which means “to imitate”. This expression is, nevertheless, imprecise as the main point of bionics is to apply the exact principles of mechanisms into technology.

Talking about “bionics” in terms of parametric design is still ambiguous. Professor Andrzej Samek who is a precursor of bionics in Poland claims that “(…) Bionics is a search for a model in nature, recognition of its mechanism and its transformation into a technical device. Architects are very accomplished with the applications of bionics – for example the one-kilometre-high skyscrapers

---

[2] Computer Aided Manufacturing – the technology combining designing with manufacturing in CNC technologies.

[3] The presented characteristics is not a comprehensive description of all trends and design methods. The author of the article merely introduces the concept of parametric design which is strictly related to all of them. The exact descriptions were specified in his other works.

that are based on the structure of redwood and cedar. Innovative buildings draw inspiration from nature much more than machines.” [5]

Let us consider the degree of the influence of nature in alleged bionic architectural objects. While electric engineers are capable of reproducing a nerve system in a very detailed way, architects and construction engineers can only copy simple forms and shapes (a joint between a leaf and a stalk → palm vault), but without the material’s structure. Małgorzata Solska[4] separated these two problems by introducing the concept of “architectural bionics”, claiming that “[bionic structures] are the forms containing the most characteristic features of the nature and comprising generalisation and synthesis of their natural prototype”. [6] In order to avoid further misunderstandings the idea of “bioinspiration” was introduced, which is the case while attempting to apply the mechanisms of nature into architecture, applied art, industrial design etc. (see fig. 1). Bio-inspiration would include an attempt to faithfully reproduce the shapes only through the analysis of the geometry of the original object.

The bionic architecture in its most visible form focuses, inter alia, on the analysis of organisms’ construction and the adaptation of their mechanisms. This does not only comprise the reproduction of shapes but also the transformation of the principles of the tissues’ structure. Bionics, in any field, should therefore focus on the analysis of the process itself, rather than on an analysis of its effects. However in the case of architecture analysis of development process for example structural elements appear to be too complex.

BIOLOGICAL ARCHITECTURE

This area is still fledgling. Lidia Klein in her article titled „Living architectures. Biological Analogies in Architecture of the End of the 20th Century” states that “biological analogy” is a way to look for the principles of the development and the evolution of living organisms. By that she does not mean copying the process precisely but only the key rules of organisms’ functioning, development and structure.

A relevant experiment was performed by Ernst Haeckel in 1862. He published a set of 100 cards containing several hundreds of drawings depicting living elements of both fauna and flora. Haeckel’s drawings showed common features inside one species without taking into consideration individual deviations. This approach is necessary as only the generalization of principles allows for

[4] M. Solska, PhD – The Institute of Architectural Design, Krakow University of Technology.

the optimal reproduction of the desired feature. The bio-architecture is focused on the analysing of the effects, not on the analysis of the process itself.

Fig. 1. Bio-inspired architecture - movable elevation of the building operates in analogy to the human pupil, but does not use the same processes (by Aedas Architecture). [7]

BIOMIMITECTURE

This idea has appeared very recently on the architectural scene. Biomimitecture derives from organic architecture but is much more radical. It envisions integration with the surrounding environment to the point where the border between architecture and nature is no longer visible. Beside visual effects, another equally important condition is that architecture should not be an alien element but part of a functioning ecosystem (see fig. 2).

PARAMETRIC ARCHITECTURE

Although this conception seems to be the easiest to be characterized, assigning individual architectural objects to it is not obvious. It is often impossible without the architect's description of his work. Parametric tools allows for the creation of both cuboid and double-curved surfaces. An object's shape, colour and style does not define it as being parametric.

Fig. 2. The house in Bolton by Make Architects. It does not interfere with the surrounding landscape but became its integral part (by D. Mandal). [8]

The method that is crucial here. It is not about the project itself but the creation of object's geometry whose elements are connected by elementary parameters. To sum up, parametric architecture[5] is the objects that were designed with parametric design tools.

[5] The presented article highlights the terms connected to the parametric design applied to architecture. However, the parametric methods can also be used in contractions, industrial design etc.

The present inaccuracies in the terminology are caused by the emergence of new design possibilities. Throughout the history of architecture geometries based on perpendicular lines, sometimes circles and ellipses were dominant. The replacement of paper and pencil by computing power allowed for the creation of complex shapes. The huge explosion of architectural forms based on smooth, floating lines created by parametric software gave a misleading impression of the equality between parametric and organic architecture. In case of the first one "(…) curvilinear shapes emerge from fitting to initial conditions (…)". [9] Cuboid buildings are the effect of civil engineering technologies, which are not always compatible with the optimisation of architectural premises.

The question whether parametric architecture was born before or after the induction of CAD technologies is still controversial. Having a deeper insight into the history, one can find a plethora of examples of using parameters in a design process.

The golden ratio has been constantly used since the ancient times. At that point it was treated as a guarantee of aesthetic composition in the field of architecture, art and engineering. The golden ratio proportions were found to be harmonic and although it was known at that time, they reproduce the standards found in the nature. The analysis showed that the proportions of the golden ratio are present in the structure of crustaceans' shells and in the spiral arrangement of the Milky Way. The discovery made by the Weissow brothers in 2003 (proven in 2010) was also intriguing. They have noticed that also brainwaves are based on the golden ratio.

Closer to modern times, in the post-war architecture, Le Corbusier promoted in his designs Modulor proportions. For Unité d'habitation in Marseille, the site plan is based on the 15 values associated with the Modulor (see fig. 3). Character's diagram which measures 226 cm (in fact, depending on the project the values were between 216 and 226 cm) is based on studies of Vitruvius and the Vitruvian Man by Leonardo da Vinci. To a large extent, still is connected with the golden ratio. "According to Vitruvius, beauty of architecture lies in the perfection ratio called by him "eurythmia" (good rhythm), which can be achieved through proper numerical relationship between the main dimensions of the building and its other elements. It allows to apply the module. Vitruvius shows the human body as a model of eurythmia" So the first place in the creation of space was put at human ergonomics.

However, one can intuitively recognize the differences between the application of parameters in modern architecture and its primitive usage during the ancient times and renaissance. The main idea of contemporary parametric tools is to create the relations between object's geometrical components in order to be able to analyse the biggest amount of possible solutions in a short period of time. This process allows for a more optimal outcome than in case of traditional designing. The optimization process concerns also costs, usable floor surface and the amount of daylight in rooms. The parametric relations found in historical architectural styles only dealt with facade compositions and special arrangements. Composition is obviously not overlooked in modern architecture but its significance was decreased on behalf of the economics of the development process.

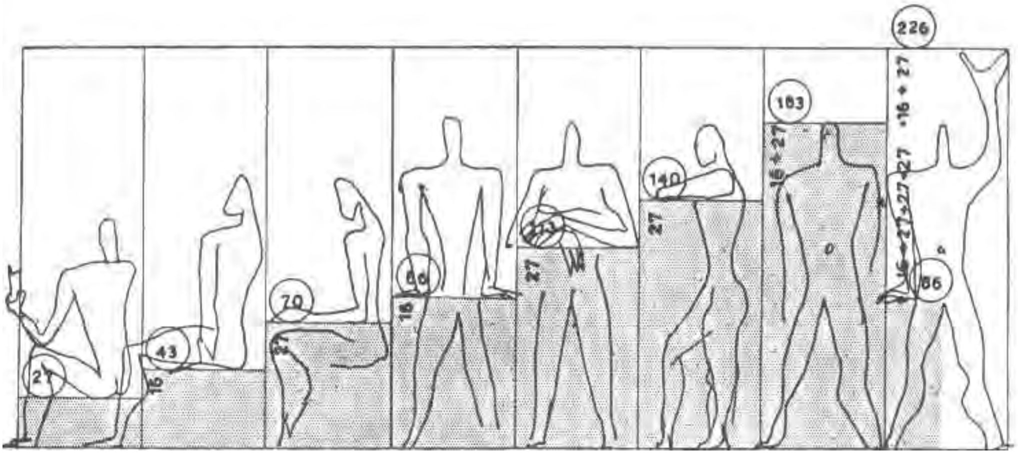

Fig. 3. Sketch showing the proportion resulting from MODULOR (by Le Corbusier). [10]

The analysis of the above problems is characterised by the graph shown below (see fig. 4). The two groups were created due to the contribution of the elements in the design process. Concepts based on the natural environmental inspirations form the modern design trends group. All of the mentioned trends have one thing in common – they all draw inspirations from the nature. The differences between them is the degree of its adaptation in a project.

All of the currently known parametric design tools are classified into the category of designing methods using a parameter as an element connecting the whole geometry of an object. Two of them – generative and evolutionary design – are based on producing the algorithms generating the set of outputs comprising within the parameters domain.[6]

[6] Generative design results in one solution within the area. Evolutionary design in a given space of time, provides solutions with the increasingly accuracy of the final shape optimization. This process is also called parametric design morphogenesis.

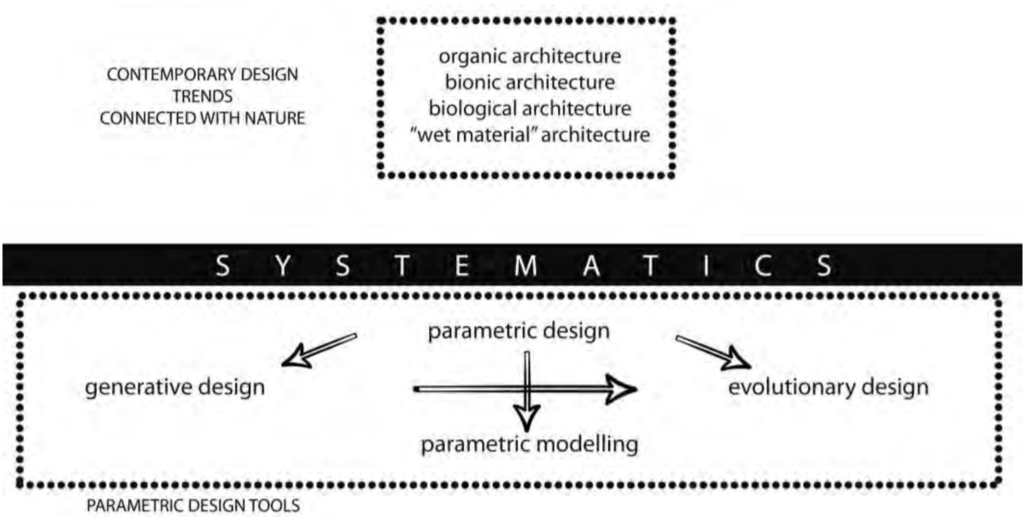

Fig. 4. The graph of systematics of problems concerning the modern design process.

PATH OF DEVELOPMENT

More and more disciplines are becoming inspired by nature. Both living and non-living parts of natural environment strive to conserve the maximum amount of energy and billions years of evolution perfected their strategies. It may seem that natural environment which is very changeable and mobile contrasts with static architecture. Apart from the already mentioned relations of parametric design to nature, the new topic of architecture of wet materials is being explored. A research on the living building materials is being carried out. The introduction of living tissue into a static construction may seem irrational and there are still many unresolved problems. This concept surpasses the limits of parametric architecture in its current form.[7]

On account of the presented work, the role of an architect in the design process should be taken into consideration. While he uses parametric tools, he no longer directly decides the object's shape and composition. In this case the formation of architecture comes down to (but is not limited by) defining the rules the designed object should obey (see fig. 5). The designers have never been more conscious about what they are doing. Intuition was replaced by rational consciousness. Discussions on the topic of parametric architecture comes down to the debate on choosing the correct relations and the values of

[7] The author does not exclude future role of parametric design in describing the biological processes of living tissues, and even to control of their growth.

parameters. This is a proper direction only in case of the objects being totally based on parameters which is, nevertheless, the truth for currently implemented parametric tools. Since geometries created in such a way look spectacular, they are applied to facades, roofs and basic shapes of high buildings. However, unless computing power and our ability to create complex algorithms undergoes a revolution, designers will have to keep on intermingling their intuition with orthodox algorithms of parametric design.

Fig. 5. A house designed by Oron'a Catts'a i Ionat'a Zurr'a, with the collaboration of The Tissue Culture & Art. Project. Pig wings (2000-2001). The research was carried out in a bioreactor. The 3D printed frames (4 cm x 2 cm x 0,5 cm) that possessed a desired porosity were covered with a tissue. The tissue gradually colonised the artificial structure. The outcome is presented above. [11]

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FLOCK BEHAVIOUR AND CONTROL

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In this paper we present the results of the Flock Behaviour and Control workshop cluster during "Shapes of Logic Conference 2015". During the event, students got familiar with the techniques of both visual and sound real-time data processing. The second topic presented for students was behaviour-based approach of design process, mainly based on the mathematical rules set up by Craig Raynolds on the swarm behaviour. The aim of the cluster was to investigate potential use of both tools together, creating advanced, real-time algorithms.

INTRODUCTION

During the conference "Shapes of Logic workshop" (Wrocław, Poland, March 2015) was organized workshop on motion and sound tracking used in order to control emergent multi-object virtual flocks. In the workshop participated: Agnieszka Kozłowska, Damian Paszkowski, Tomasz Zamojski, Emilia Marcinkowska, Monika Więcek, Maria-Eleni Papandreo, Evanthia Beristianou, Agata Bonisławska. It was leaded by Adrian Krężlik and Kacper Radziszewski. This paper is a report from that event with a short description of theoretical background.

THEORETICAL FOUNDATION OF THE WORKSHOP LEADING TOPIC

A new direction in creative process has emerged based on a „bottom-up" approach to both algorithmic design and computer aided fabrication stage. Also called, „behaviour-based", these solutions do not require a high level of control or organization on the system, which enables avoiding complex computer programs and high computing power. Bio-inspired algorithms became foundation for any non-linear approach of achieving optimized results for advanced geometrical issues. Collective behaviour of life organisms represents macro-scale intelligent system based on a set of simple rules at local level, which provides designers an efficient and simple tool generating bio-inspired complex results, thus virtual control of swarm behaviour and its possible application became leading topic for our cluster.

Flock also called swarming is a collective behaviour characteristic to animals of similar size, race, breed, generally speaking physical appearance which aggregate together and act as one bigger, multi-elemental organism. From mathematical point of view it is an emergent behaviour arising from a simple set of rules, built by self-propelled entities, which does not need any central coordination, often referred as bottom-up system.

WORKSHOP PROCESS

During the workshop students had a chance to develop both theoretical and practical knowledge. Introduction lectures were followed by general exercises focused on the bottom-up design techniques and real-time data processing. Each of the students had a chance to develop their own idea on the possible practical use of the provided tools. Each of the projects were presented during the workshops summary along with the participants of the rest of the cluster. Selected projects were also presented during the shapes of logic conference following the workshops.

The starting point for all the tasks during a five-days workshops became Craig Reynolds work (1986) “Flock, herd and schools: A distributed behavioural model“ [1]. He described a mathematical model of swarm behaviour which follows three simple rules: alignment, cohesion, adhesion.

With a use of tools such as Grasshopper plugins, Anemone [2] and Boids Library [3], aided by scientific knowledge of specific species collective behaviour and followed by a visit to Wrocław Zoo, defining a true representation of simple swarm behaviour was achievable by all of the participants. Basic knowledge in programming bottom-up behaviour, enabled all of the members finding an application of boids systems in real-life goals.

The second task being developed during five-days-workshops was real-time control of flocks behaviour by external analog triggers. The set of tools used as a medium for generating data based on human gesture and voice consisted of Firefly [4], reactivision [5] software and webcams, microphones, Kinect [6] camera and fiducial markers. The first type of real-time data input device- Kinect- enables to track motion of up to two people in a provided space. Visual data collected with Kinect's two 3D depth sensors and RGB camera was represented in Grasshopper 3d software as a set of points corresponding with actual positions of joints of a human body. The second data input device, webcam in a tandem with open-source Fiducial Markers 7], gave a possibility of two-dimensional type, position and rotation capture. Each of the markers was represented as three points, position and two orientation points, and a unique tag, enabling matching properties for each of the markers separately.

The other input device used during the workshops was microphone. Real-time captured voice frequency from 85 to 180 Hz was transformed into a numerical data flow via Firefly Grasshopper 3d add-on, providing a motion-less control of the agents behaviour.

SELECTED STUDENTS PROJECTS

The workshops participants, after several step by step exercises, were able to work independently on developing an algorithm based on the real-time data flow and transforming into the simple flock behaviour. Following projects aim to present the workshops' outcome and the way authors differently approached the topic they were given.

Real-time motion tracking and interactive simulation algorithm

The first project, by Agnieszka Kozłowska combines Kinect motion tracking with a set of data storing components. Based on the movement of one of the hands, positions are stored briefly drawing in space a spiral. In order to add realistic representation of a pulled string, the curve is given a spring force, which is influenced by the movement speed (see fig. 1).

Based on the working algorithm, student was able to define the restrictions in the movement freedom of the provided hardware- X-Box Kinect Camera. The most noticeable inconvenience was limitation of the camera angle. Low-cost tool, Kinect Camera, is adapted for standing activities, which can cause camera stream to loose vision and duplicate output data, while the tracked person partially reaches the bounding camera area. The second restriction is related to camera tracking speed. Kinect camera works less accurate with a grasshopper3d software, than with the dedicated gaming platform X-box. The adjustment of the movement speed is required, which should not exceed the value of 1 meter per 2 seconds for 1.0.0.68 Firefly release.

Presented approach gives a foundation for further projects and investigation in a creative use of the provided tools in the modern theatrical performances or early stage motion tracking used for motion in architecture field itself.

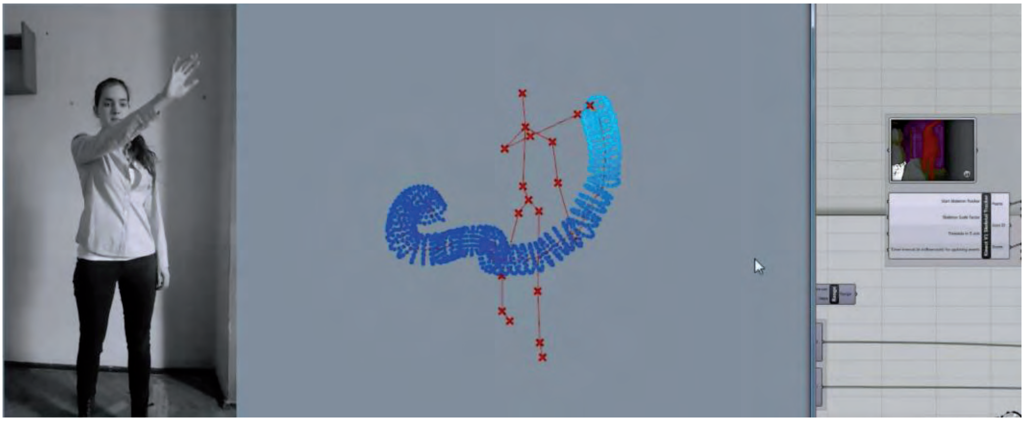

Fig. 1. Real-time motion tracking, actual RGB camera view, simulated skeleton view, algorithm's depth depended layers view.

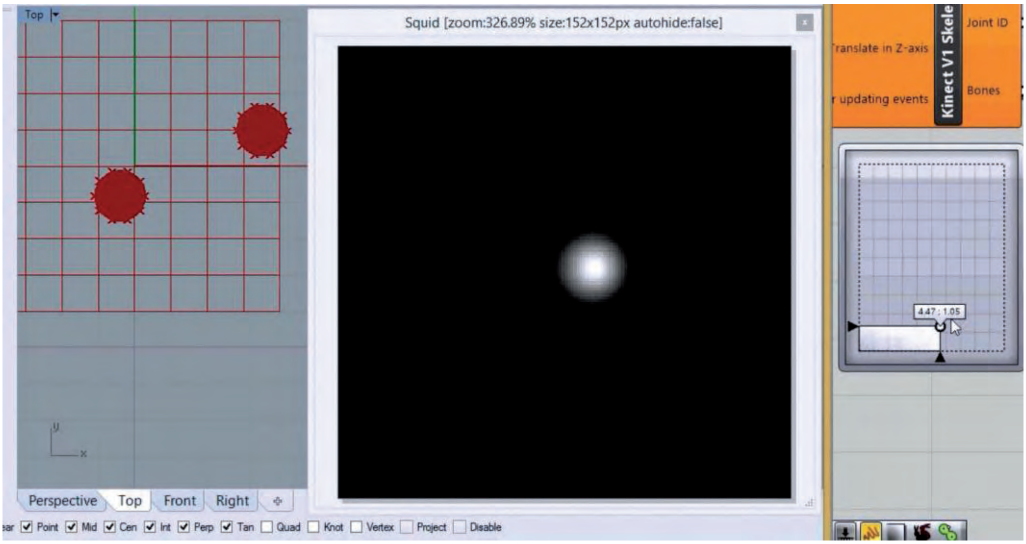

Fig. 2. Vectors display representing position of the evaluated dots, Squid generated visuals, algorithm's points coordinates control panel.

Advanced visual and sound effects algorithm

The second project (see fig. 2), by Evanthia Beristianou, presents the technique of reversed use of the provided tools. Based on the movement, position and distance between the two points visual and sound output is generated. The closer the points are, the stronger are the fields surrounding the dots, which at the specific distance are merged based on the metaball geometry rules. The drawings were generated with Grasshopper add-on Squid [8]. Apart from visual effects, high-frequency sound is being generated based on the distance of the agents, which was achieved with Firefly for Grasshopper 3d add-on.

The algorithm was controlled by points moved by computer cursor position. Further algorithm extension could include possibility to track the position of the objects movement, based on the sensors connected to each of the objects, external motion tracking or set of the distance sensors of the one of the objects.
The author's work was developed on idea of sound alarm system, informing about objects approaching towards moving people, who's natural senses may be damaged or less functional in a specific circumstances.

One of the possible ways of developing the project is using the algorithm idea in a connection with an open-source electronic prototyping platform, which will allow to create an autonomous, interactive, electronic device. This kind of device could be used both by pedestrians and integrated in vehicles electronic systems.

SUMMARY

The workshop resulted in seven different projects, based on the on the real-time data capture and processing along with bottom-up design approach. Each of the students' work brings the early project that can be developed either with the provided tools or as a general idea to be developed. The vast potential use of the emergent design techniques opens up a new way of thinking about the process of design itself, which can be successfully extended by tools before not associated with architecture, resulting in fresh ideas.

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REDEFINING DEFINED
Questioning the accepted norms of living spaces

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Architects must abandon architecture of domination over space, these strong, rigid, immovable forms and notions of predefined norms of a fixed society. "Πάντα ῥεῖ" (panta rhei), "everything flows" said Heraclitus, and change is the only constant thing in our lives, affecting the direction of our thinking and acting. We need to design change, design the conditions that will allow this liquid modernity to flow.

What I wish to achieve here, is a starting point. The new approach of design should be to design the conditions that will make a situation possible. You cannot design perceptions, norms and understandings, but you can design the components of a space where all those are going to be formed and happen. The "event" we shall design, should be the starting point of a situation that will follow. An object, a space, an event, an interactivity, which will allow for the emergence of a new architecture; the ephemeral.

Questioning norms, through a personal approach and while expressing my personality within the creative procedure of a project, I try to avoid my encapsulation into any form of regulation and set myself free of constraints in order to let the legitimate outcome emerge through a framework that will be formed under a spectrum of criticality.

"The inferno of the living is not something that will be; if there is one, it is what is already here, the inferno where we live every day, that we form by being together. There are two ways to escape suffering it. The first is easy for many: accept the inferno and become such a part of it that you can no longer see it. The second is risky and demands constant vigilance and apprehension: seek and learn to recognize who and what, in the midst of inferno, are not inferno, then make them endure, give them space." [1]

INTRODUCTION

"The idea that we, as designers, are committed to providing maximum "choice" or maximum "freedom" seems to be arousing us to unprecedented height of metaphysical speculation. The nature of this phenomenal outburst is such that it is absurd to imagine one could be dispassionate or uncommitted about it. This is because it is a way of changing the world and not a way of describing a given state of the world." [2]

"Living in an age of uncertainty" [3] and "liquid times"; one of the most challenging aspects of what we do as designers is declared at the above phrase of Robin Evans. Does the key of that phrase lie somewhere in the notion of "change"? Do we need to affect drastically our surroundings and fight against the pathetic acceptance of pre-determined normality? According to Heraclitus "change is the only constant in life"; and now, more than ever, due to the evolution of technology and the structure of our societies, this change is not just constant but it is intense and rapid as well. That is the reason why we need, not only, to be part of it but to manage to take the reins of it. We must not let this "situation" conquer our everyday life because of the passive attitude we choose to have; but, we must act under a spectrum of criticality, which will allow the emergence of the legitimate outcome; and allow us to achieve our goals and satisfy our true needs, away from the encapsulation of pre-accepted norms and perceptions that imprison our personalities. This "new" must be adjustable and transformable, in order to be able to stand across this constantly altering "situation", which we are called to administer.

The notion, which declares that design provides the opportunity to designers to decide about the form and function of a design, most times is understood in the wrong way, from both sides, the one of designers and the other of users. Ostensibly, this is how things work, but none of the above can or should "decide" on their own, without the contribution of the other about the form and function of a creation. Design is a cooperation; it is a co-existence of needs, skills, knowledge and criticality. Design lies somewhere between the satisfaction of user's needs and the knowledge and skills of designers allowing the emergence of the legitimate outcome; always through a filter of criticality.

CRITICALITY IN DESIGN

"…understanding the critical is not an option or a luxury that can be dispensed with in favour of allegedly more rigorous pursuits, but is integral to any adequate comprehension of what design achieves and the processes whereby it does so". [4]

Criticality is acceptable and legitimate; especially in design and its practices, since it's "forcing" the design procedure to the emergence of an exceptional "designed product". But, should criticality be synonymous to design; something that is not just a characteristic of its practice, but design itself? Design begins, where designers observe and analyse under a critical spectrum, the potentials/possibilities of an "object", to form a new "object". Objects emerge through the "objectification of sentient awareness", as T. Rosenberg mentioned referencing E. Scarry, [5] moments of perceptions which designers are called to use, and through their gift or talent in combination to a critical approach to form the future object. Moreover, as C. Dilnot writes: "…critical perception seizes shows, exposes and announces the truths of a situation and its potentiality as it sees it". [4] This "power", the CRITICAL perception, can be translated through design into an actualized form; and at the same time, not only originates a design but crucially gives it orientation, an essential feature of a "designed product". Through this procedure "…design is capable of touching upon a merely "ersatz" version of design..." [4] that serves as a substitution, but determines the truth in relation to things and produces useful products. Designers have to act under the sense of a critical attitude by which they will be able to behave in an appropriate way, sustaining their important role and revealing a multidimensional approach that they are engaged in. This will lead to the transformation of the world, in terms of critical thinking.

Therefore, criticality is just a part of a complicated system, that designers should take into consideration to make their practice an integrated creation. It is crucial and it does play an instrumental role to the procedure of design, determining the "settings" of it. However, design must emerge through "a series of axioms or criteria". [4] Using a network (a system) will enable designers to design in a different way, taking into consideration alternative aspects of a situation, designing without following the norms and the "already made", but extracting the new needs from the users, passing them from a critical prism that will lead to the meeting (of those new needs) through new designed solutions. Designers, "must critically analyse the assemblages that determine and are determined by design". [5] It is the only way they will be able to use their abilities in such a way that will lead them to create "designed products". The difference between "things" created/designed by a designer and "objects" manufactured/produced by a craft maker is "thinking"; [6] Designers are "obliged" to think critically and interweave a context into their creation, while a craft maker mainly reproduces forms without having the need to analyse, understand and provide reasons for its manufacture. This can only happen, when designers do not isolate the "object" from its environment or its user. Once the whole network/environment is taken under consideration, we talk about a totally different situation.

DIAGRAMMATISM AND ARCHITECTURE

The way someone approaches a "situation", shapes its meaning. An object (or a subject) isolated from the environment and disconnected from the network where it belongs, does not mean anything. The essence of it, lays on the way in which it is incorporated into its environment and interacts with its network. However, the meaning of that object/subject can vary, and that depends on the approach of the person who observes it (see fig. 1).

Fig. 1. A breakdown of the network behind the arco lamp by Castiglioni Brothers. Part of "Spaces of Practice - Diagrammatism, and the unpicking of design's contextual "assemblages"" project held during the author's studies at Goldsmiths University, January 2014.

Trying to narrow and target my point, I would like to focus on my field of study, architecture; however, because of the size and the complexity of architecture as a study-case and for the purpose of this essay, I will analyse one aspect of it, this of housing architecture referencing one of my previous essays; where the parameters that were taken as primitives for this research were: User/Personality, Structure, Location, Time, Function, Idea/Perception and Society/System (see fig. 2) At the beginning, a general approach of architecture was made under those terms, translating them into perceptions of every term, individually, in different parallels or even diametrically opposed plateaus.

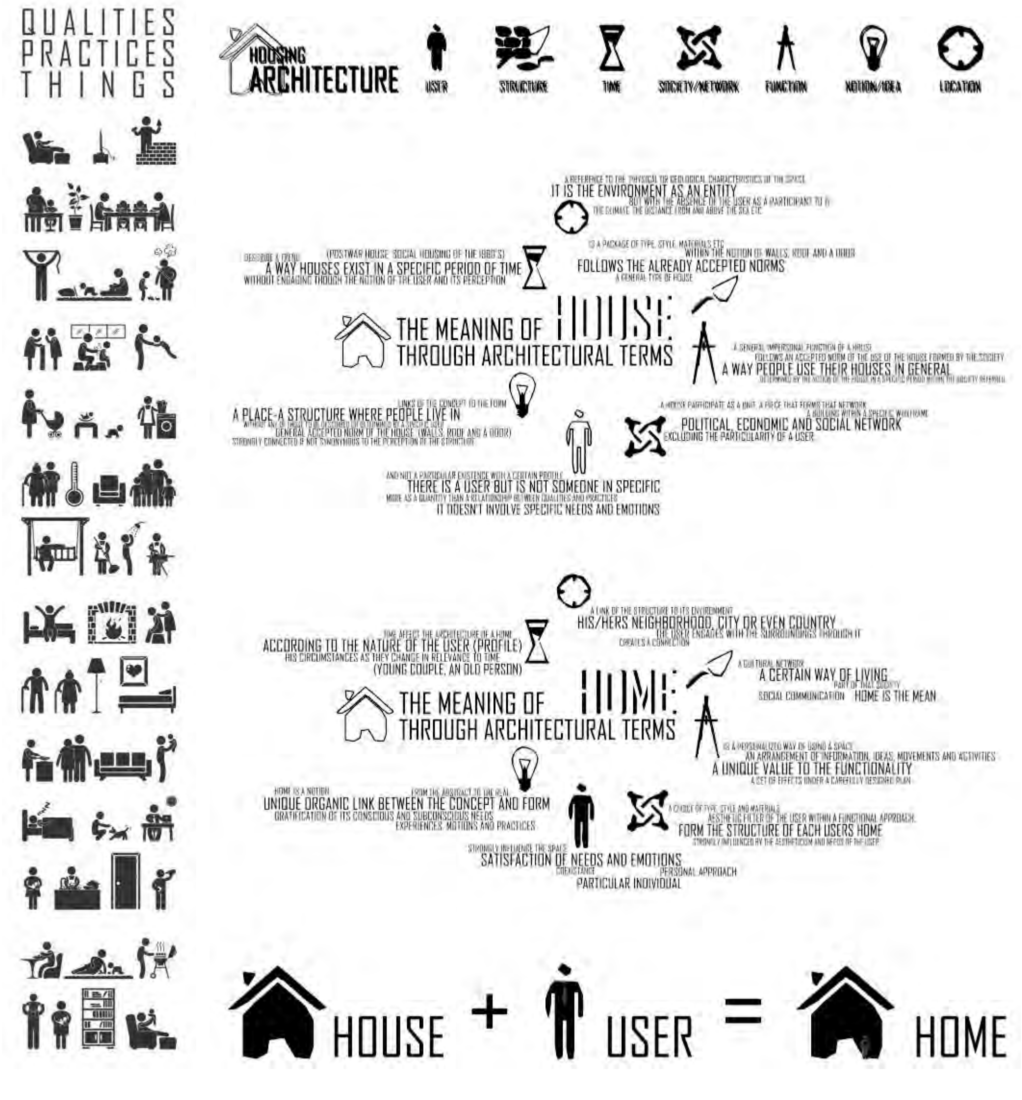


Fig. 2. Use of the method of diagrammatism. An effort to break down the notion of house/home in general terms (left image) and through some specific parameters (right image). Part of "Spaces of Practice - Diagrammatism, and the unpicking of design's contextual "assemblages"" project held during the author's studies at Goldsmiths University, January 2014.

Then, those parameters were used to approach and analyse the terms of "HOUSE" and "HOME", two vital terms for the comprehensive of housing architecture. Different meanings of each term was defined by the critical study of data such as terminology of the terms, interviews from experts (architects) and data, gathered from random people, answering just to simple questions such as " what is a house/home to you?". The terminology was made for each parameter individually, but the interviews were made in a general concept of the perception of those terms. Taking those approaches, provided the opportunity to analyse each piece isolated, but in the same time, to identify the relations between them. [2]

Summarizing, this process of disassembling architecture into general terms, the analysis through the same primitives of two vital terms (HOUSE and HOME) and the application of the results into an example, had provided the opportunity to overcome the "facts" and see beyond borders, where the truth perceptions were revealed. Hidden behind datum, the perceptions of “ancient precedent" [7], customality and the global spread of a "type of life can be marginalized". Being part of a system, of a society that defines a certain way of life where "things" should work or even have to be in a predefined way [3], blocks the vision and leads to the acceptance of norms/principles, even if they do not actually serve or satisfy to the extent that they should. [7] To solve those kinds of problems, one must re-approach, reset and redefine what is going to be designed. The example that R. Evans gives in his book, where passages (the whole system of movement) used to be a route for consecutively rooms for over 300 years, and its replacement with corridors; can easily capture what is happening in those moments of obscurity when, just because we accept or even being captivated from the status quo we cannot "dream", visualize, get over the ordinary and design the NEW; which will serve not only a principle but the whole milieu that surrounds it; the interconnections of all the elements that constitute that "future design object". Although, we need to be able to judge critically a situation, filter the world around us, set ourselves free from accepted norms and predefined decisions, and only then we can proceed to design. Bernand Tschumi mentioned that: "In architecture in particular, the notion of de-familiarization was a clear tool. If the design of windows only reflects the superficiality of the skin's decoration, we might very well start to look for a way to do it without windows. If the design of pillars reflects the conventionality of a supporting frame, maybe we might get rid of pillars altogether."; [8] questioning the foundational notions of architecture in his effort to make clear that we shouldn't consider anything as a datum, but to re-assess it and redefine it before we accept it. [3]

THE NOTION OF CHANGE

Designing houses which are going to become homes for other people; I need to use my "tools", my personal approach and expressing my personality for a place which other people will call “home”. This is one of the main concerns I have, whenever I design a HOUSE/HOME. Trying to overcome this problematic issue, I was trapped trying to identify what I could change in the way I design a HOUSE, in order to provide the possibility to the users to transform it into their HOME. Whenever I tried to design a HOME for a particular person, or a particular group of people, even if I managed to end up with the legitimate outcome at the time; as soon as I finish my design, or sometimes even during the design procedure, I feel that I am designing just a temporary solution to a "problem", which soon enough will alter, causing misfits to the proposed solution and the situation which it is called to solve. Returning once again to the quote I cited at the very first of this essay in combination with the citation of Heraclitus and his quote "Τὰ πάντα ῥεῖ" I find that change is the key which will unlock the potentials of design in the future. Quoting Paul Virilio who said that "we are not dealing anymore with technology of construction but with the construction of technology", I move a step towards my project and my concerns and say that probably the answer to this contemplation is to stop designing for the change but design the change itself.[8]

Change, is the aspect that constantly affects the above parameters, even the user and his/her personality.[9] After pinpointing "change" as a parameter of my design, everything seems to come together, forming a new world, a new plateau where I was called to act on. Change, forms the new stage where I need to set my scenery and let my play implement. Everything seems totally different and the notion of the word “temporary” does not have a negative tone anymore. The word “ephemeral”, suddenly acquires a new meaning. It seems like the solution of the problem comes with the same name; but with different meaning, thanks to a different approach. The problematic issue was that, my designs were not able to last for long, because of the structure of our contemporary societies and the function of the world around us which changes extremely fast and intensively. Now, I realize that, the solution is to design the ephemeral. The aim though, is not to replace something with something else, but to manage to evolve it at the same time. So, the question here is: how you manage to improve something that is already good enough, since it does satisfy your needs, with something else which will be able to reach and reveal the satisfaction of the need you don't even know you have? It is vital for architects

[8] “Architecture is not about the conditions of design, but about the design of conditions that will dislocate the most traditional and regressive aspects of our society and simultaneously reorganize these elements in the most liberating way, where our experience becomes the experience of events organized and strategized through architecture”. [8]

[9] “Evans pointed out that the desire to achieve a set of prescribed terms of conditions for domestic space is relatively recent phenomenon-and more importantly that the meaning of these terms has not always been the same. The situated-ness of a concept such as comfort, for example, depends on cultural, temporal and technical conditions and so varies enormously from place to place”. [7]

and designers to approach their design, keeping in mind that change must be a factor of the design, a parameter that will filter all the above and transform them into distorting their initial notion and substance. If change is taken for granted, the design approach of living spaces, will totally be altered and redefined (see fig. 3).

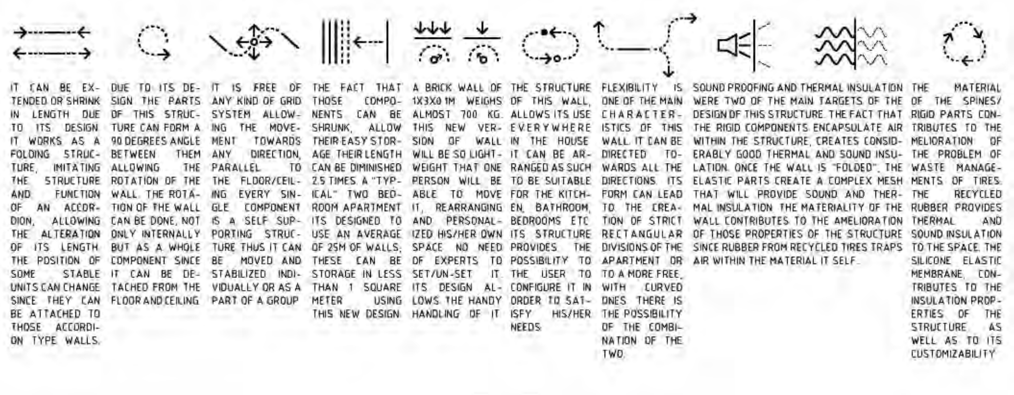


Fig. 3. Properties of the “new” Wall. Under the spectrum of the “ephemeral” design, the parameters of the “new” wall are set. This new wall, is not following the conventions and normalities. It stands against the accepted norms and it is suggesting a solution to a contemporary, ephemeral problematic while in the same time allows for reconfigurations. Redefined, resolves new problems and it is ready to respond to those which are about to appear in the future. This wall is designed in terms of designing the change itself rather than design for the change.

We need to face our environment under a different spectrum which will allow us to see beyond the borders of the norms of our societies. We need to advance our societies, using architecture; and this will be possible through architecture and after our escape from the "regulation box" which imprisons us. We need to search and discover the alternative, the radical intervention which will provide us with the ability to evolve and will lead to the emergence of the "new". This “new” will reveal the potentials/possibilities of the new everyday life; a life/ which will be totally different from the one we all know. An unfamiliar everyday life which will be able to remain as such, if one wishes to. The user will be able to set and adjust the rules of the game, and not the other way around.[10] We must not obey architecture, but we should be able to arrange, handle and adjust it according to our terms and in our way, as users and as

[10] “In the public eye, architecture is about comfort, about shelter, about bricks and mortar. However, for those for whom architecture in not necessarily about comfort and geborgenheit, but is also about advancing society and its development, the device of shock may be an indispensable tool... Architecture in the megalopolis may be more about finding unfamiliar solutions to problems than about the quieting, comforting solutions of the establishment community.” [8]

designers too. Architecture has to be "opened up"; and needs to be demystified (see fig. 4).

B. Tschumi, argues that: "In a mediatised world, this relentless need for change is not necessarily to be understood as negative. The increase in change and superficiality also means a weakening of architecture as a form of domination, power, and authority, as it historically has been in the last six thousand years". [8] Is this truly a weakness of architecture? And if it is, can this change? What if we -as designers/architects- manage to use this weakness as our new powerful weapon, with which we will conquer this "mediatised world and this relentless need for change"? Architecture should not dominate the space, but it should provide the chance to the user to dominate it, in his/her own terms.

"You may think I'm being facetious, but in today's world where railway stations become museums and churches become nightclubs, a point is being made: the complete interchange-ability of form and function, the loss of traditional, canonical cause-and-effect relationships as sanctified by modernism. Function does not follow form, form does not follow function -- or fiction for that matter -- however, they certainly interact", [8] said B.Tschumi and I couldn't agree more. The interaction between form and function can be achieved by the designing of change. Today, people need to have the ability to interact with their environment, they need and they should have the ability to change, transform and arrange their environment according to their own terms.

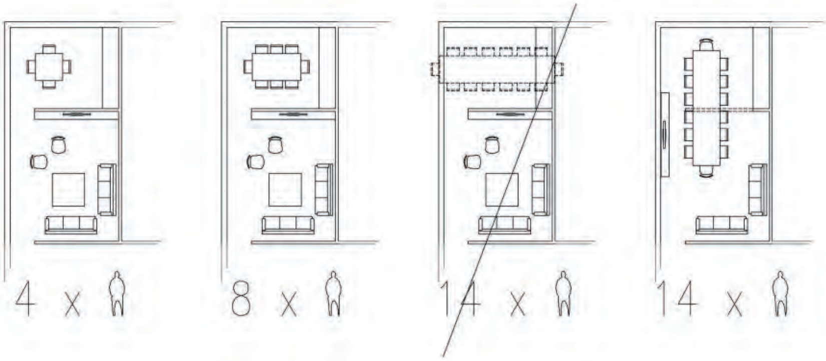
Designers must design in contemporary/today terms and whatever comes with it. The constant change, transformability, complexity, interweaving, and in general this "unprecedented combination of programs/ activities and spaces" characterizes our everyday life and thus should characterize our everyday design.

"Architecture finds itself in a unique situation: it is the only discipline that by definition combines concept and experience, image and use, image and structure. Philosophers can write, mathematicians can develop virtual spaces, but architects are the only ones who are the prisoners of that hybrid art, where the image hardly ever exists without a combined activity." [8]

Since the above statement is true, we shouldn't treat architecture as an image, as a plastic form, as a sculpture, at least not only like that, but understand it and treat it accordingly, as an interaction of an image and a frame, as an interaction between the sculpture, the viewer and the sculptor, as an interaction between this plastic form, its creator, its user and its environment.

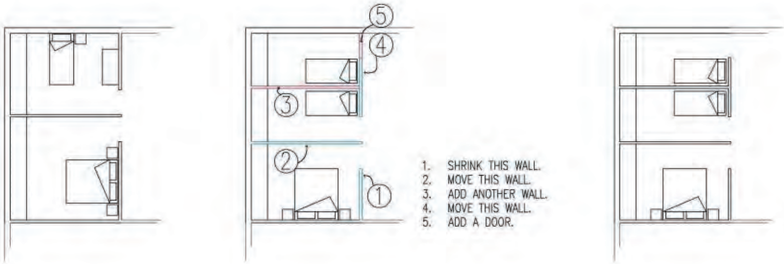
PARTY

HAVING A DINNER FOR 12 BUT YOUR KITCHEN CAN ONLY TAKE 8? BY RECONFIGURING THE SPACE YOU CAN GAIN EXTRA DINING SPACE FROM WHAT WAS DESIGNATED AS LIVING ROOM.



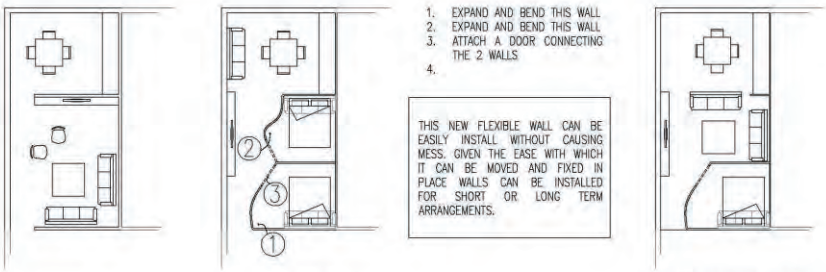
NEW ARRIVALS

WITH THE ADVENT OF A NEW BABY YOU MAY NEED TO RE-DESIGNATE SPACE TO ACCOMMODATE THE NEW ARRIVAL



GUESTS

OVERNIGHT GUESTS CAN BE ACCOMMODATED BY, FOR INSTANCE, DIVIDING AND REASSIGNING THE LIVING ROOM TO PROVIDE EXTRA SLEEPING ARRANGEMENTS FOR AN OVERNIGHT STAY



2 ROOMS [SHORT TERM (DAY)/LIVING ROOM LOST]

1 ROOMS [LONG TERM (MONTH) / SMALLER LIVING ROOM]

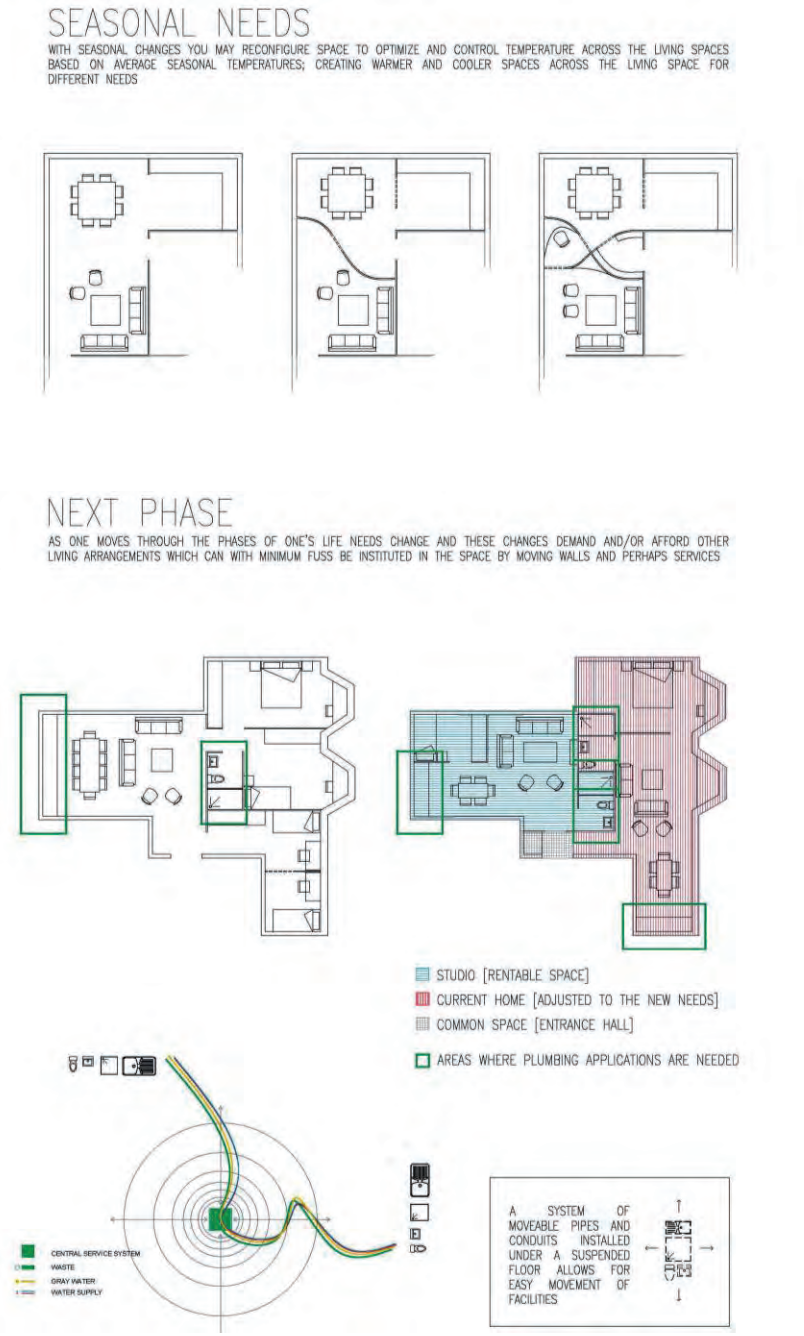


Fig. 4. Use of a flexible wall. Architects must design taking into considerations the requirements of the new ephemeral approach. The user must be able to use the space in her/his terms and not the other way around.

With this project I am raising a question; I am not designing an object nor a space, but I am trying to set a scenery where plays will take place. Through the design of events, of the potentiality, we design the environment where different interpretations of different possible acts could take place, revealing a new activity, allowing the emergence of a new-pure reality. Not one in particular with a predefined scenario, but an event, not only in action but in thought as well.[11]

CONCLUSION

"The event is the place where the re-thinking and reformulation of the different elements of architecture, many of which have resulted in or added to contemporary social inequities, may lead to their solution. By definition, it is the place of the combination of differences." [8] What I wish to achieve here, is a starting point. The new approach of design should be to design the conditions that will make a situation possible. You cannot design perceptions, norms and understandings, but you can design the components of a space where all those are going to be formed and happened.[12]

The "event" we shall design, should be the starting point of a situation that will follow. We cannot control or foresee, exactly this "situation", and we don't want to, because there is where the beauty of this architecture lays. An object/a space/an event, as also as an interactivity, will allow the emergence of a new architecture, the ephemeral one. The etymology of the world “ephemeral” [εφήμερος<αρχ. ἐφήμερος<ἐπί + ἡμέρα] describes a situation which last just for a day and usually has a negative meaning. In this case I would like to redefine that world and give it a positive aspect, where ephemeral will be something that last for a short time, meeting the expectations of our contemporary everyday life that moves in intensive rhythms and liquid circumstances. An ephemeral "event/space" will allow to cross-programming and trans-programming being able to be adjust and co-operate not just passively but actively as well.[13] [8]

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[11] For Foucault, an event is not simply a logical sequence of words or actions, but rather “the moment of erosion, collapse, questioning, or speculating of the very assumptions of the setting within which a drama may take place -- occasioning the chance or possibility of another, different setting.”

[12] "Architecture is not an illustrative art; it does not illustrate theories. (I do not believe you can design deconstruction.) You cannot design a new definition of cities and their architecture. But one may be able to design the conditions that will make it possible for this." [8]

[13] "If architecture is both concept and experience, space and use, structure and superficial image -- non-hierarchically -- then architecture should cease to separate these categories and instead merge them into unprecedented combinations of programs and spaces. “Cross-programming,” “trans-programming,” “dis-programming:” I have elaborated on these concepts elsewhere, suggesting the displacement and mutual contamination of terms." [8]

I am trying to question the norms, my perceptions and the ones of the society I am living in. Through my personal approach and while expressing my personality and character within the creative procedure of this project, I try to avoid my encapsulation into any kind of "regulation boxes", I set myself free of all the holding backs and let the legitimate outcome, the "new", to emerge through a framework that will be formed under the spectrum of criticality and the lenses of the above parameters.

Architects must abandon the architecture of domination over the space, by strong, rigid, immovable forms and notions of predefined norms of a fixed society. "Τὰ πάντα ῥεῖ" said Heraclitus and change is the only constant thing in our lives which indicates the direction of our thinking and acting. We need to design the change and design the conditions that will allow this liquid modernity to flow.

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CREATIVE DYNAMICS OF MEMORY

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The challenge of creating an artificial mind starts from the Second World War, with the birth of Artificial Intelligence· a kind of curiosity for science information, directly associated with cognitive psychology. Artificial Intelligence considers the brain as an algorithm in which the memory uses different inputs, automatic selection and a neural substrate, but has a main structural problem: to give substance to the mnemonic process of this artificial mind and to place it there, where it will be able to adapt. In which terms can memory found in artificial life and robotics contribute to the design process? In addition, or on the contrary, morphogenesis nowadays is also seeking elements of false memory, or even loss of memory. So, what can be really accomplished with a computer memory?

Through a project based on bottom-up computational design, this contribution will explore the ways in which the above mentioned characteristics, combined with the extensive use of smart materials, change the way we interfere with the built environment. Specifically speaking, is the building of a centre for people suffering from post-traumatic stress disorder, itself, able to help them forget? Could the space accelerate and work as a complement in the forgetting of an event?

HOW TIME AND SPACE AFFECT ONE'S MEMORY AND VICE VERSA

"The maintenance of representations" is what Aristotle defined as memory, back in the 4th century BC. Ever since, the issue of memory, its nature and its properties had a variety of scientific fields concerned themselves with, while still belonging to the most popular topics of discussion and research. Architecture, with its different expressions over the centuries, is a necessary condition of the material hypostasis of memory and its recreation· it encountered the concept of memory with different, but equally crucial, each time ways.

Memory is defined in relation to time. It is an ideological link which connects the desired future with the evenly desired past, which is in the meantime re-built. Its difference with history is that it reinterprets and specifies relationships, which are incorporated in the context of direct experience. [1] On the other hand, history is a reconstruction of what no longer exists. Collective memory, which is the essence of historical events of a society, is recorded in cities, the place where material history of societies is composed. Therefore, the space is where the way of the human's integration in time is reflected. The city is an accumulation of traces of its past moments and its forms. The spatial palimpsest is paralleled with the human soul, which as another recording machine, captures the memory. [2] Memory is in need of the support of the space and is rendered impossible without the image. It is a function of the part of the soul, in which imagination is also included. The renovation and alteration of memories, and quite often their selective oblivion, are as well characteristics of memory.

TO FULLY UNDERSTAND THE IMPORTANCE OF MEMORY, ONE SHALL COMPARE AND CONTRAST THE HUMAN MEMORY TO THE ARTIFICIAL ONE

Even though humans are the only beings who can combine the memory of the past, the contemplation of the future and the awareness of the time being, thanks to the concept of consciousness, memory is fundamental to nature as seen in various examples. One such example is that of the slime mold Physarum polycephalum, which lacks any kind of brain or nervous system. It uses, on the contrary a clever mechanism to remember where it has gone, and escape from difficult situations. It leaves, for accuracy, a mold trace as it moves, with the help of which it can later identify the areas that it has already visited. [3]

Nowadays, there are undoubtedly common features between human and technological memory. With the emergence of cybernetics, concepts of memory and history have been redefined thanks to the new kind of temporality introduced alongside the theory of evolution. Cybernetics is governed by the need of deleting the by-that-time memory. Nevertheless, it brings new conditions in the processes of recording and storing of data. While trying to explore this new world, architects focused on the interaction and dialogue between the system and the designer, participating in the search for artificial intelligence. The great mnemonic capacity is by its nature a compulsory condition for the creation of intelligent machines. The progress in artificial life (which emerged as an outcome of artificial intelligence), combined with a broader scientific context, contributed to the development of the self-awareness of robotic systems. The field of robotics in general is concerned with creating mechanisms capable of sensing, planning and acting to accomplish a goal. Or as the eminent roboticist Rodney Brooks said "we should build complete intelligent systems that we let loose in the real world with real sensing and real action". [4] Foremost is the need to achieve complex goals, the need to interact with a complex, dynamic environment, while ensuring the system's own dynamics, the need to handle uncertainty, and the need to be reactive to unexpected changes. These needs influence how robotic systems are designed, how they operate, and how they are validated (and even what it means to be validated). [5]

The architectural robotics must overcome the purely formal achievements· they must explore ways to improve life, enhance existing areas and support human interaction. Architecture and technology - specifically the hybrid architecture-robots should support human activity, react normally and perform according to the needs and desires of the users. They must, also, provide the means and redefine urban living standards. Answers to life problems and opportunities will only come from computational robotic solutions, but through some way these technologies embedded in the built environment, will help advance the interaction between people and their environment in order to create social and psychological importance areas. For the philosopher Feenberg: "The technology is not just a tool, it has become an environment, a way of life." The architectural robotics are more than an aesthetic approach, a stylistic alternative, a technology question· they are a way to develop new spatial patterns in support of human activity. [6]

These ideas are reflected in the plans of the English-visionary architect Cedric Price for Fun Palace (1961), with which he introduced in architecture the concept of interaction. The design of his idea referred to an ephemeral multi-programmed full-day entertainment centre that combines communications technologies and standard metal elements in order to create a "machine", able to adapt to one’s needs and desires. He, himself, refers thereto as a set of pieces, rather than as a building, suggesting that it would be extremely unlikely to have twice the same form. [7]

An example that tries to study how architecture can respond to the demands of an active public space rather than as a passive environment is the Topotransegrity project of Robert Neumayr. It is a dynamic structure that constantly assesses the environment and is redefined by the changing conditions, thanks to sensors that perceive the human touch, embedded in the mesh structure. It is by nature a component system which reacts and adapts to specific spatial events occurring thereon. Of interest is the memory function that has been added. Specifically, it tracks as the time goes by, traffic patterns by separate users and it affects the topography of the surface showing the most frequent paths. It has however also a kind of "amnesia" that slowly removes these traces on the surface of the structure, restoring the topography in its original form after a period of non-use.

It is then understood that a key feature of interaction is the possibility of feedback and redefinition. During an execution, an object can refer to his memory, which has saved previous actions, in order to compare, to identify, to exclude· it reminds us of the operation of human memory. It can always redefine the relationship between action and reaction. It provides to the interaction the element of the "unexpected", every experience is unique, since it works with a given pattern of behaviour, but it works subjectively. [8]

Although scientists strive to push the boundaries of automated architecture, at the moment their creations are more like works of art. No doubt it will be quite some time before humans begin handing over their mortar shovels and band saws to the robots. Right now the emphasis on algorithm-driven materialization is more philosophical than practical. But letting computers take over the creative process can yield some truly stunning creations. Who knows what robots might build in the future by following their structurally sound yet unpredictable algorithms? [9] The only certainty is that researchers see robots as not just fabricators or labourers, but as a medium fully involved in the design and construction process. They call it a “real-time platform” that can be advantageously unpredictable. Ultimately, they plan to begin developing these robotic groups for experiments in designing with emergent and agent-based AI systems, which rely on unpredictable outcomes through strictly defined logics and presets. Additionally, they expect that robots will become sophisticated enough to work in tight and complex spatial conditions, enabling them to work directly on the construction site.

MEMORY AND MATERIALITY. A CASE STUDY

Memory manifests itself as an intermediary between perception and action, while the robotic systems offer new possibilities in architecture. This study of the relationship between architecture and human memory, as well as artificial memory, led to the elaboration of this diploma project. Its challenge is to explore the way in which the space could accelerate and work as a complement in the forgetting of an event. The design of a support centre, for people who suffer from post-traumatic stress disorder, along with residences for the healing period, is the main topic of this thesis. The spatial distribution of the different functions of the complex consists of: I) one central part, where the organizational operations, as well as all of the collective activities, such as meals, yoga and Tai Chi exercises, group therapies, occur. II) individual residence units (8).

Specific information about the position of the units and the relationship between them, was generated after studying self-organized systems, based on groups of floating agents programmed with defined characteristics. Most importantly, however, the information led us to the design of a shelter, as shown in the next page, which unifies all of the units and creates a micro-environment, a miniature of the real-world, a world without their memories. As the study of one unit proceeds, aspects of the morphology, volume and perforation of the unit were explored with the help of tools such as metaballs, agents, isosurface.

Fig. 1. 3D Visualization of one unit.

Various experiments were done in order for the desired volume of the units to be found. Materials used: Concrete, plaster, clay. Once the curvature was established, a perforation logic had to be found, which would also play the role of the static system. Images show an example of random agents running on an existing mesh and leaving their trails on it, the logic of which was used in the modelling of one unit. Materials used: thread, glue. Having studied about the needs of a patient who shall pass a certain time of his life in such a dormitory, it became clear to us that the levels of his willingness to socialize, of his stress and of his eager to interact with nature are unstable. They all depend on which phase of the treatment the patient is going through and are thus influencing the dormitory itself.

The architectural aspect of the unit was formed from experiments explained previously. It also contains a knitting system in the frames of most openings, which using smart materials (shape memory alloys) adapts to the needs and desires of its tenant, for light transmittance and extroversion. This smart material has the ability to remember two different forms, so depending on the phase, the wires are either fully stretched or repelled from the centre of the opening in order for more light to come in the dormitory. There are three different layers of shape memory alloys, one for each of the phases (see fig. 1-3).

Fig. 2. 3D printed model of the centre for people suffering from PTSD.

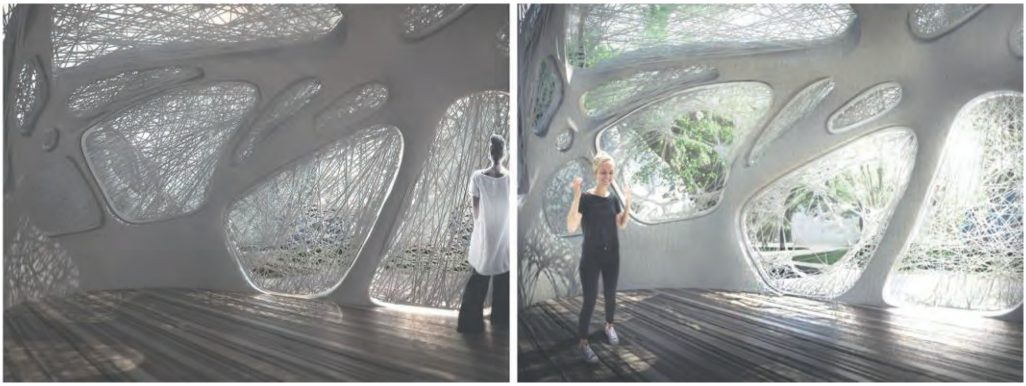

Fig. 3. 3D Interior visualization of the two different phases of one unit.

OBLIVION, UNCERTAIN, UNEXPECTED. COULD THESE TAKE PART IN THE PROCESS OF ARCHITECTURAL DESIGN?

The memory, in both its cognitive and technological function, refers to the processes of encoding, storage and recovery of data. Consequently, the existence of information is a basic prerequisite for the mnemonic creation. In humans, the reception of information is through the senses. Whichever organ responding to a certain stimulus sends electrical signals to the brain through the nervous system of the body. In computers, the corresponding stimuli-receiving sensor were until recently the mouse and the keyboard. However, thanks to new emerging technologies and interdisciplinary research in the fields of cognitive science, neuroscience and artificial intelligence, efforts are being made so that a kind of intelligence and consciousness can be conveyed into machines with hopes of a possible perception of the space-time environment in which they belong. The ultimate goal is to become autonomous extensions of the mental and productive processes of the man. “If we want to attribute intelligence to an object, natural or artificial, the relationship developed is not that of a master and a slave, but it’s a relationship between two intelligent partners who have the ability to self-improve”. [8]

Several contemporary examples are heading towards this inquiry, the most important perhaps of which is the example of the flying robots of Gramazio & Kohler. It combines precisely this awareness of space and the integrated information and is dynamically involved in the creative production of an architectural project. It is, namely, a successful attempt to combine human and computer memory. Is it, nonetheless, the only way of using computer memory? The world is moving towards a post-human period, which will bring forth a new type of bio-engineered mutation (biomachinic mutation) of organic and inorganic components. Karl Chu wonders: “How can architects reform the practice of their work to meet the demands of the computer revolution?” [10]

Architecture is the means of depicting the evolution of human civilization. Ernst Fischer once stated that the form is the “established social experience” and, therefore, the transformation is the evolution, the change of these social experiences. We are talking about the memory that human civilization continuously records through the constant changes in technology, socio-political data and the forces of production. The content of architecture is exactly the memory that metabolizes the architect. Exactly as the memory is created (individually or collectively) within the social context of the space, in the exact same way it itself identifies temporal relationships. By the new concept of temporality, a new request for continuity is arisen. It has now become evident that human life is not limited to the length of a man’s life. The evolution of life and intelligence on Earth has reached the point where it is now considered possible the ex nihilo creation. The theory of evolution is clear in the relationship between architecture and computers. According to Frazer [11] architectural concepts are expressed as productive rules so that their evolution and their development can be accelerated and controlled with the help of computers. On the contrary to what Mies van der Rohe supported, that architecture is the art of combining two bricks, the emerging concept is that nowadays architecture is the art of combining two bits, two such digits that have been programmed to self-replicate into new forms of emerging relations and sets. [10] Having in mind the self-replicating system of von Neumann – which is a prototype of a contemporary computational system – and the increasing influence of artificial life in architecture – like genetic algorithms - , once senses a shift in architecture from morphodynamic to morphogenetic design and construction approaches, or at least a combination of these approaches.

From a different perspective, an important feature of human and computer memory is undoubtedly the capacity, both in terms of size (storage capacity of information) and of place (where information storage takes place). In computers the data is stored in a designated area, even if it happens to be fragmentary information. In humans, the process of remembering involves activation of neurons where the encoded information is located. But in this case, certain neuros can encode various memories. Depending on their placement in the brain (human or computer), on the structure and on the duration, the memories are divided into short – term and long – term. The computers have already the equivalent of a short-term memory used by the machine as a temporary storage space. It is no coincidence that both computers and biological organisms must be based on some form of short-term memory. However, not all of the information is saved in the long-term memory, some memories are lost· hence the concept of lethe – oblivion is involved. And it makes sense, because in order to operate effectively, one has to forget. The ever-increasing capacity of computational memory gives us the possibility to store vast amounts of information, but when we remember everything, memories lose their value.

What is lost from memory, consciously or unconsciously, is to be completed by the imagination, resulting in distortion and change of memories. Consequently, we are talking about possible false memory, for unexpected evolution, a concept which morphogenesis nowadays seeks in its design processes. The random plays an important role in determining the uncertainty, from which new forms emerge. Mark Burry adds that emerging critical theories have no hesitation in accepting or even in rewarding the random or the mistake. Nonetheless, the information stored in the computer is never altered. It is therefore reasonable to wonder and have an interest in the results that would occur from a collaboration between a machine and a human, emphasizing on different functions of oblivion. During this information age, memory is the one that prompts us to design and the one that specifies both the purpose and the manner.

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A NEW PROPOSAL OF COLLABORATIVE PARAMETRIC DESIGN METHOD

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The architectural design always was and will be a collaborative project between architects, engineers, and other specialists. As is well known, modern digital technologies and globalization have changed the architectural design in general.

In recent years, growing more complex projects and the new research in the majority of universities require a more demanding architectural process to cope with these new data. Thus, thanks to the universal interactivity of the internet and the new flow of data, the contemporary architectural practice is adapted.

According to all the above, the architectural design process always changes because the software always updates with new tools and the development - innovation are in the first line of progress.

The ‘clever’ and proper use of various programs and technologies can bring the desired result in a quick and easy way. The storage and retrieval of design data through databases, the workflow and the exchange of information through cloud technology, the open-source programming platforms (scripting) in conjunction with parametric programs and software of B.I.M. and AEC industry (through I.F.C. protocols) can bring flexibility to the architectural process.

A collaborative design platform will be considered as successful if it involves and supports most of these features so that it can be adopted by different user groups of scientists. Additionally, it can further enhance the possibilities to explore new areas in the design process. The technological developments of the last decade set the framework for a new approach to the same concept.

INTRODUCTION

Pierluigi Serraino, in his lecture "Form Follows Software" at ACADIA 2003, presented several case studies where the software used had a direct impact on the design outcome. [1] In other words, "Form Follows Tools" is referring to both design and digital methods and the duplex relationship between these two processes. Obviously, the available digital tools equipment, as well as the software used, has largely influenced the repertoire of forms in digitally produced artefacts. This is in line with the famous phrase by William Mitchell that "architects tend to draw what they can build and build what they can draw". [2]

In recent decades, new methodologies have emerged in architectural designs that exploit the computer as a design tool. This has generated a varied set of digital skills and a new type of architectural knowledge. The present paper attempts an approach towards such a theoretical background based on the concept of computable functions. This approach results in an abstract perspective of digital design that enables a grouping of contemporary digital design methods and an understanding of their logical relationship.

THE WEB

Thanks to the increased internet speed, it is now possible to collaborate in real time and transfer huge amounts of information - data almost immediately. Furthermore, an average computer user is more educated on the internet, being able to handle basic tasks online. Therefore, the design may be available through networks to international partnerships and joint research programs with a great sense of flexibility.

The web – cyberspace is gradually rebuilt in the multidimensional environment by entering into the ever new technologies and data. So, as an evolution of HTML (html5 last edition in 2014), the 3D HTML has recently appeared. Plus, the data formed in three dimensions instead of plain text having multiple layers - layers of information as data - trees three dimensions. In this way, the data volume can be both much larger and complex, but without lacking in speed and flexibility. Increasingly, new programs appear to support 3D HTML while allowing interactivity and pumping info online from further away databases.

The Data-Driven Forms are forms of data fields. Depending on the data changing forms because the algorithm is associated with the rotation of the data. In the digital world, the transition of information from one node to another is achieved in real time (real time). The feature is that these searches have to do with a 3d dimensional digital model where navigable given the real world. In these examples, cyberspace is an actual architectural space.

BIM – AEC INDUSTRY

Building Information Modelling (BIM), also called n-D Modelling or Virtual Prototyping Technology, is a revolutionary development that is quickly reshaping the Architecture - Engineering-Construction (AEC) industry. BIM is both a technology and a design process at the same time. What is also very important is that the BIM system enhances cooperatively the design, offering the opportunity to many disciplines of the manufacturing sector to contribute to the design of the model prior to its implementation. BIM removes barriers and bridges communication between the architect, the engineer, the manager of the premises, the contractor, and the owner, providing reliable transmission of information during the project. Generally, BIM is an integrated process, which improves the understanding of the work and the construction, providing predictable results. This enables a more precise coordination of teams working in the production, in order to make informed and timely decisions during the process, thus ensuring the success of the project to be completed.

A new file format, an ISO developed by BuildingSMART[14], is I.F.C.[15] The I.F.C. is the only open standard '3D object - oriented' form of exchange used by B.I.M. systems. The disposal is free to all software vendors. The I.F.C. provides 3D geometry representation for all project components and standardized according to the market, customized data for each item, such as materials, profiles, and features. The applications used by the different disciplines can easily be adapted accordingly and identify the relevant information they need through the database (see fig. 1).

B.I.M. Programs currently used are Catia, Revit, Digital Project, Vector Works, Bentley Systems Microstation etc.

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[14] BuildingSMART is the worldwide authority driving transformation of the built environment through creation & adoption of open, international standards. http://www.buildingsmart.org.

[15] The IFC specification is developed and maintained by buildingSMART International as its "Data standard" (http://www.buildingsmart-tech.org/specifications/ifc-overview). The Industry Foundation Classes I.F.C. specification is a neutral data format to describe, exchange and share information typically used within the building and facility management industry sector. IFC is the international standard for OpenBIM and registered with the International Standardization Organization ISO as ISO16739 (http://www.ifcwiki.org/index.php/Main_Page).

Current trends in information exchange affect the AEC sector, as expected, whether it comes to using new software for the design process, or to keeping up with the latest cloud technology that facilitates the exchange of information. Because taker usually interacts directly with at least one industry aspect AEC, the exchange between architects, engineers and contractors become vital.

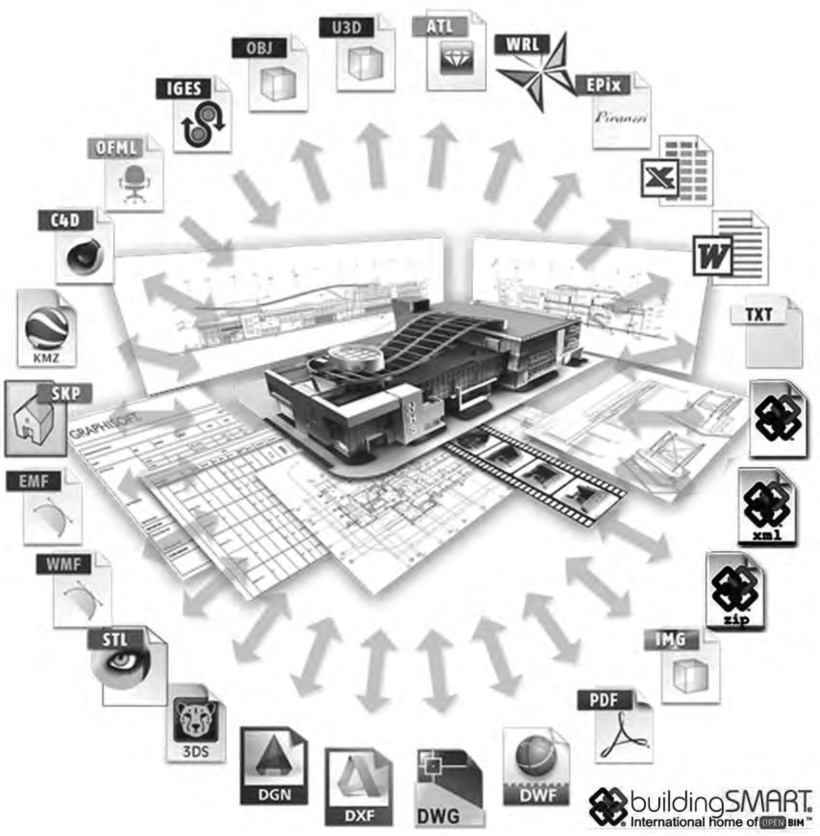

Fig. 1. The IFC file format developed by BuildingSMART (by buildingsmart.org). [3]

Considering the way the BIM movement is progressing, the possibility that BIM will completely replace CAD systems is not very distant. As the market continues to adopt BIM as a standard, BIM will continue to flourish. As the use of Cloud technology is growing, it will be easier for project stakeholders to quickly access BIM model virtually everywhere. The developments in augmented reality and similar 3d virtual technologies will allow project owners and engineers to manage their buildings more efficiently (see fig. 2).

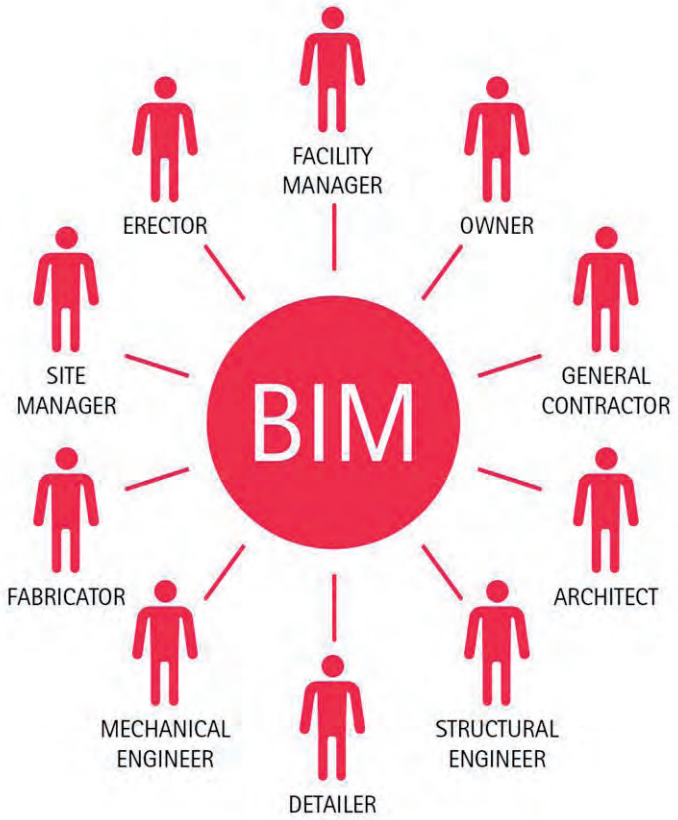

Fig. 2. BIM collaboration (by buildingsmart.org). [3]

CLOUD TECHNOLOGIES

An ever-growing technology in the technology industry is the clouds that bring freedom and flexibility both for the individual and for every kind of tech IT companies (Information Technology). Cloud Solutions enable IT transformations and concessions for people wherever they are, or what device using or what applications are or even what elements, maintaining strong security and control that IT enterprise by greatly increasing their productivity. Through cloud system, relaying information is wirelessly achieved through a remote server that works as a database abstraction and updates all the information.

As a result, AEC affected directly both the industrial architectural programs CAAD and the BIM branches, taking advantage of the new services of the cloud.

The BIMobject® is an online central database keeping all the information on the object BIM and BIM files. The BIMobject® Cloud is built in such a way that searches Engine Optimization each product published on the portal after using permalinks for each product so getting a unique address URL (see fig. 3).

Due to the event of the last decade, of the phenomenon of Big Data, the platform for collaborative design will employ a wiki-style collaboration database, so that users can have a different level of access. The database will store information of diverse formats (CAD files (see fig. 4), 3d models, codes, parametric definitions, images, xls files, g-code, and construction details) that anyone can edit. This open and rapid process of using and editing design information gives rise to an evolutionary system, where natural selection takes place and the most interesting and efficient design solutions keep being edited and modified while always maintaining previous versions.

COMPUTATIONAL DESIGN

Computational design emerges as one of the most powerful design methods of the 21st century. With this new dominant methodology, there comes an array of tools and platforms that designers can use and exploit for coping with the inherent complexity of the design. Within this domain, there are many platforms that emerge with an open-source nature and continue to grow with an impulse by the global community of computational designers and programmers. A vast sector in the software development industry is focused on research and development for the creation of new parametric tools that can offer the impossible. Parameterizations of design, process and data have been the core focus of such tools.

PROGRAMMING LANGUAGES

Today, in the context of computational design, the VPLS (Virtual Programming Languages), such as Grasshopper or Dynamo, are becoming increasingly popular, which can be explained by the fact that they are state-of-the-art, visual languages, while LP scripting languages like RhinoScript or Processing are considered as outdated languages. Modern TPLS (Text Programming Languages), such as Haskell, Python, and Design Script are designed in conjunction with precise areas primitive, with the continuous rise, so they are better alternatives to the current VPL.

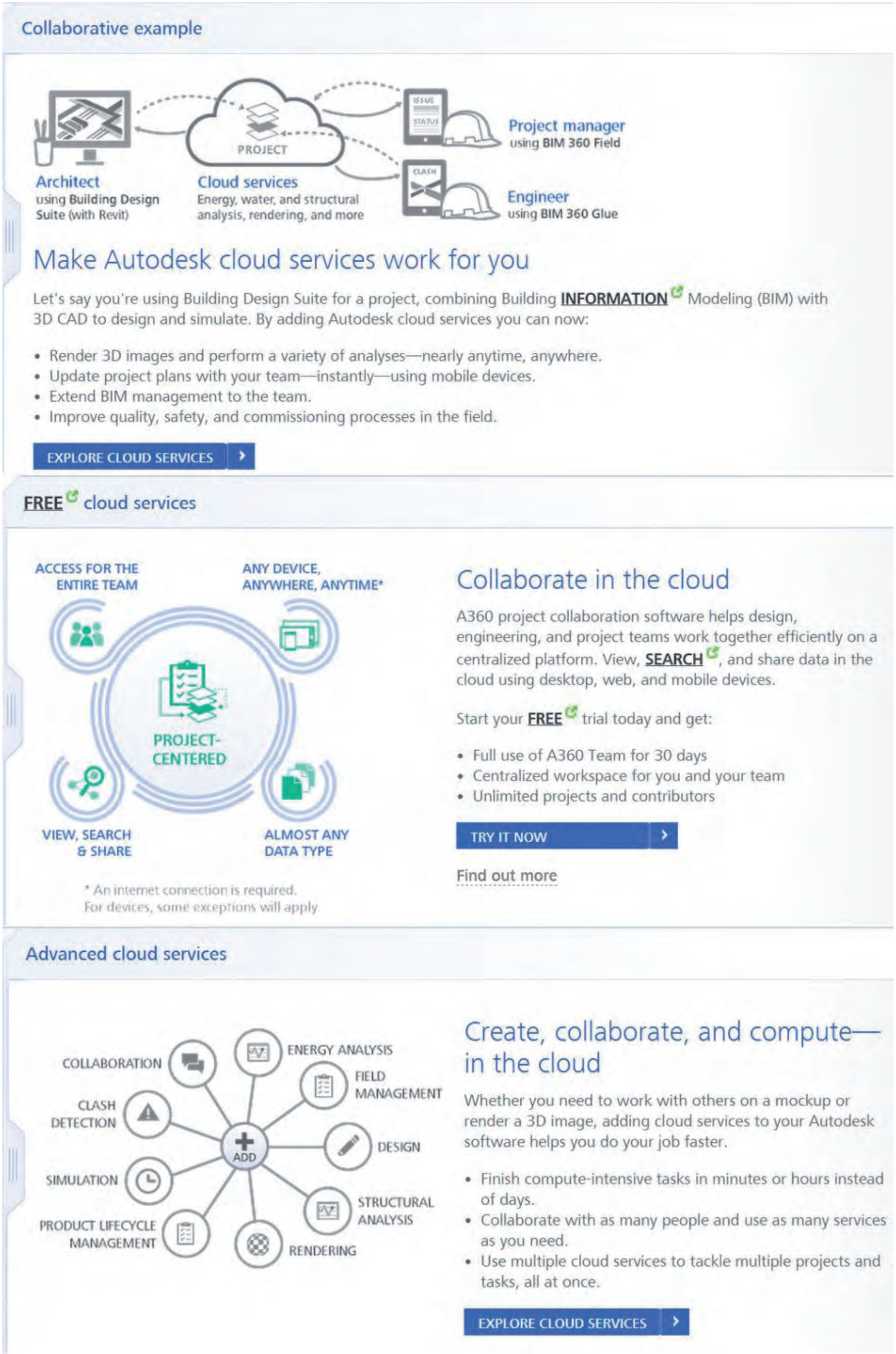

Fig. 3. Cloud services by Autodesk Inc. (by autodesk.com). [4]

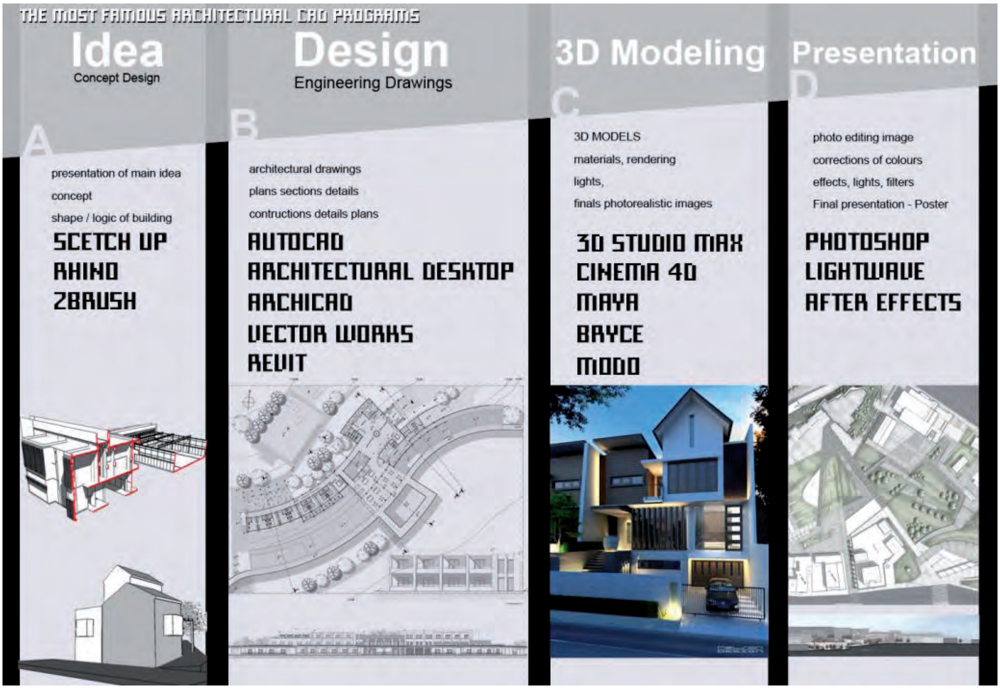

Fig. 4. The most famous architectural CAD programs.

Grasshopper is really able to overcome the limits of VPL. However, in some cases, it forces users to work at TPL, thus indicating that even Grasshopper users must learn and use a TPL. A very important advantage of Grasshopper, thanks to which it has become so quickly popular, is also that this software, which in itself is a plug-in to Rhinoceros 3D, has endless possibilities of accommodating further plug-ins, which can be developed using inbuilt software operations or by using external coding languages that are supported by this plugin, which too, are open-source. One can develop their own tools, within this parametric and generative modelling platform to extend its potential. The grasshopper platform is strongly supported by an online social blogging platform (www.grasshopper3d.com) where millions of users can share ideas or their work, discuss problems, and develop ideas together in an interdisciplinary and global way. Millions of users across the globe can potentially solve the problems of a user sitting in some other part of the world using the same platform. This idea in itself is so powerful and the possibilities are endless. David Rutten, the creator of Grasshopper, was awarded the Acadia Innovative Research Award in 2012 (www.2012.acadia.org) and Grasshopper has been widely accepted by design industries, which are not limited to architecture.

The development of programming enables the synthetic task to be approached with a great sense of freedom and extensive repertoire choices, allowing the formation of abstract structures with dynamic behaviour.

Large architectural - construction firms use mostly parametric BIM programs (Revit, Catia, Solidworks) incorporating partially BIM-script code for further personalization creating new tools, called OpenBIM (see fig. 5).

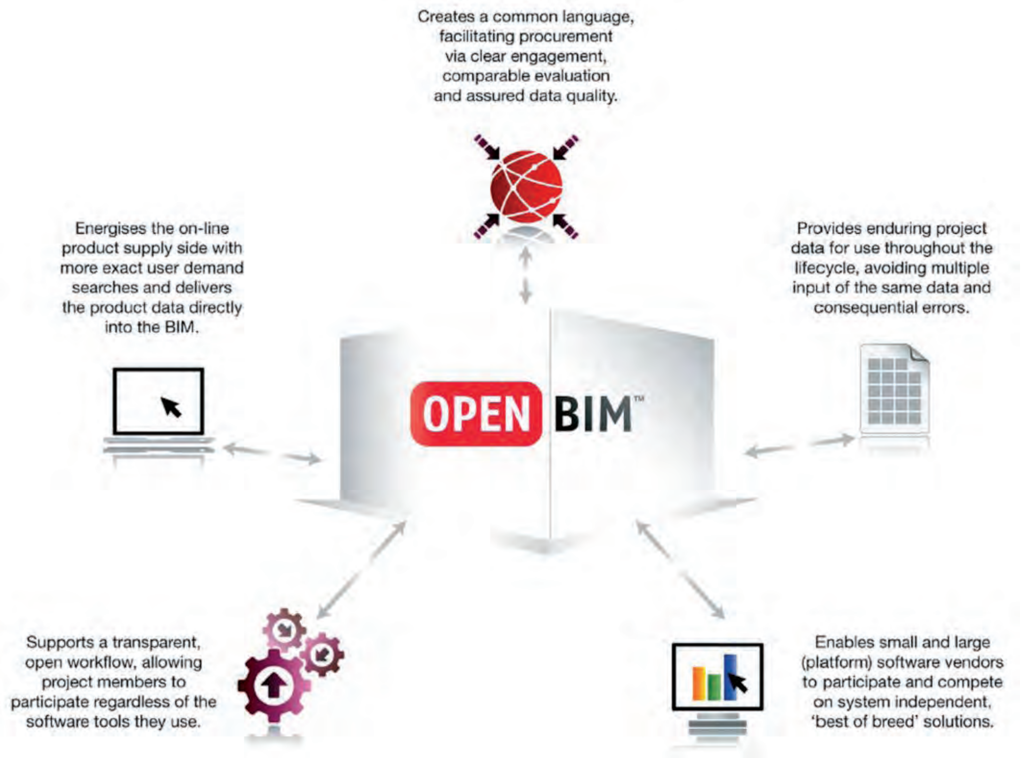

Fig. 5. Open BIM services (by openbim.org). [5]

OPEN-SOURCE TOOLS

The idea of open sourcing has been existent ever since the software (or even hardware) industry flourished. It has slowly permeated the field of architecture and design with a methodological shift to computational design. The idea of designing through codes and scripts has brought about the possibilities of using multiple platforms and languages, where the operational codes can be open-source and continually developed by the community of users themselves.

Open-source tools have gained great popularity in other sectors due to their efficiency, self-organizational character, cost reduction and constant development; they have been rarely used in the design world up to now, but the self-correcting mechanisms at work present a great potential for design projects in general.

The architect can now think and plan with the Code, or by combining the code with the project. In the new design environment, the design refers to the determinants of the components and the syntax in code relations, which is clearly specified. The result is formatted as components placed in parallel application simultaneously hold active in the matter and its morphological characteristics, components with each other to identify the encoded, calculated, developed and finalized in connection with the information, can be described by a multi-dimensional, open, but recorded, mathematical relationship - and vice versa.

DIGITAL DESIGN PROCESS

In a digital design process, attention shifts away from the form-generating geometry itself towards the logic of the underlying computational function. An important point, in this new development in design tools, is the understanding of the capabilities and limitations of the tools and, above all, their management and understanding of the theories behind these new tools (see fig. 6).

It is very important to determine the capabilities of the model - building, and the implementation of objects in CAAD systems. The benefits of these systems depend on a better understanding of the needs of architects. Through the exploration of the potential of each system is proposed as a possible solution for combine a more flexible and efficient design (see fig. 7).

The architectural process always changes because the software always updated with new tools and the development and innovation are in the first line of progress. The term 'Design Process' is translated as a production modelling tool that provides an effective way for designers to create and evaluate complex geometric design models. In the CAM, the sector may appear as 'Process Planning'. Combined with a full-fledged programming language, it is also a pedagogical tool for a progressive acquisition of programming concepts and practice for design.

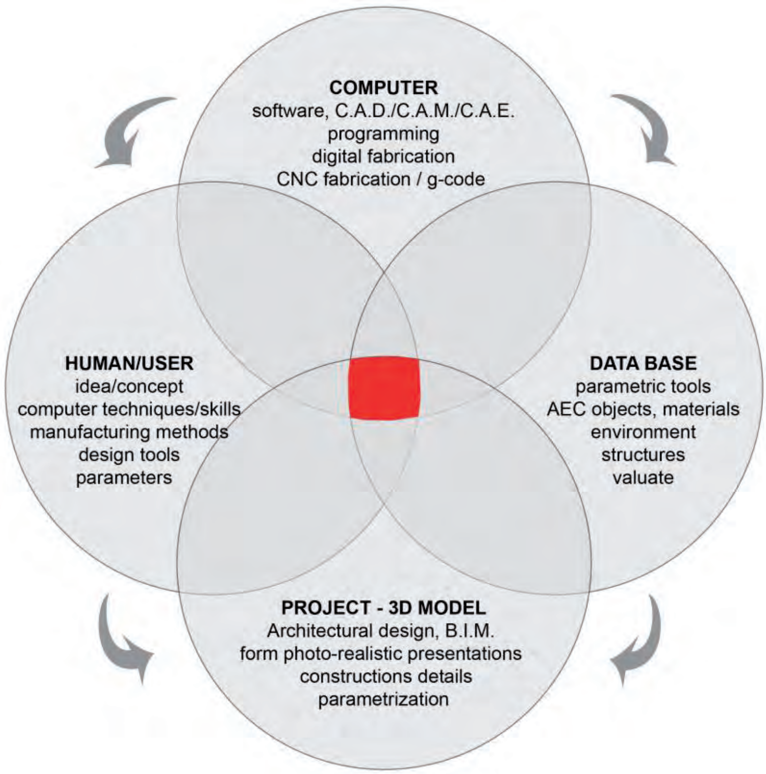

Fig. 6. Digital design architectural process.

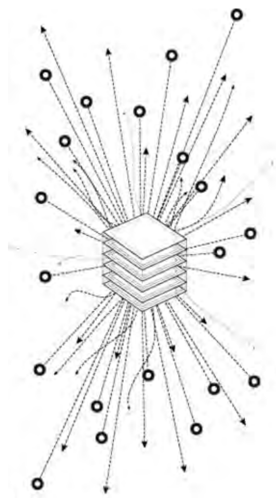

Fig. 7. The different level of access of Big Data.

The study of the concept of computability and its importance for digital design in architecture proves that the computer is not a neutral tool, but is rather actively shaping the way designers are approaching the question of design (see fig. 8).

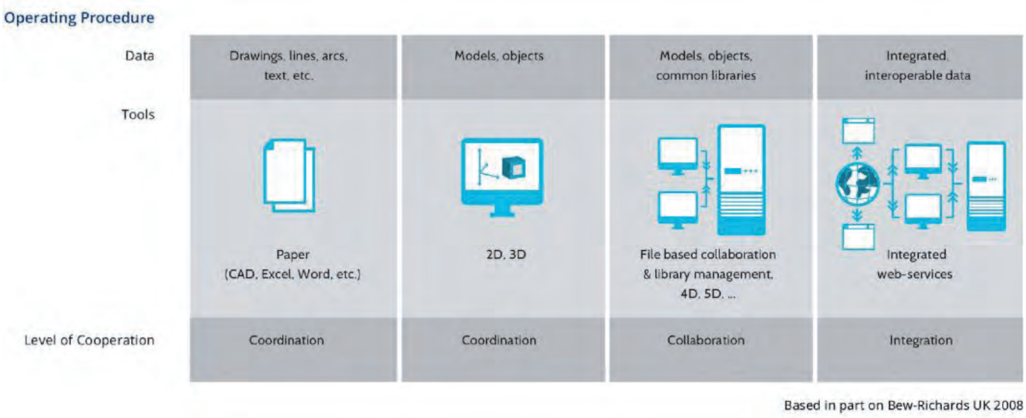

Fig. 8. BIM operating procedure. Based on Bew-Richards UK 2008 (by bimthinkspace.com). [6]

CONCLUSION

This point of view of the digital design in architecture opens up a new line of theoretical discourse in architecture that differs from the traditional relationship between architecture and design. The main proposal is to create a Common Real-Time 3D tool that can combine technologies like x-ref links in a real-time digital environment. This collaborative tool or open-source program needs to be simple, flexible and allow the architects to share and retrieve design information efficiently by introducing mechanisms of classification and data management. A method that supports a design collaboration which will allow architects to effectively share their ideas and design construction generally, in order to improve the design process.

Additionally, the platform will support parametric components and will offer the possibility to work independently on components of assemblies and parametric definitions, so that all the specialists can work simultaneously on different scales and domains and combine or modify components that were previously generated by other designers.

Finally, by combining computational design and parameters, a new vision of 3d design emerges, which includes various information, interaction with the user as well as artificial intelligence to some extent (AI). With the continuous exchange of information and data flow, interaction is achieved while combining computational design and databases-to some extent with the notion 'intelligence' as a correction of some errors in the design process in general and all this in real time. In this research topic, the ubiquitous computing[16] is the final goal… (see fig. 9).

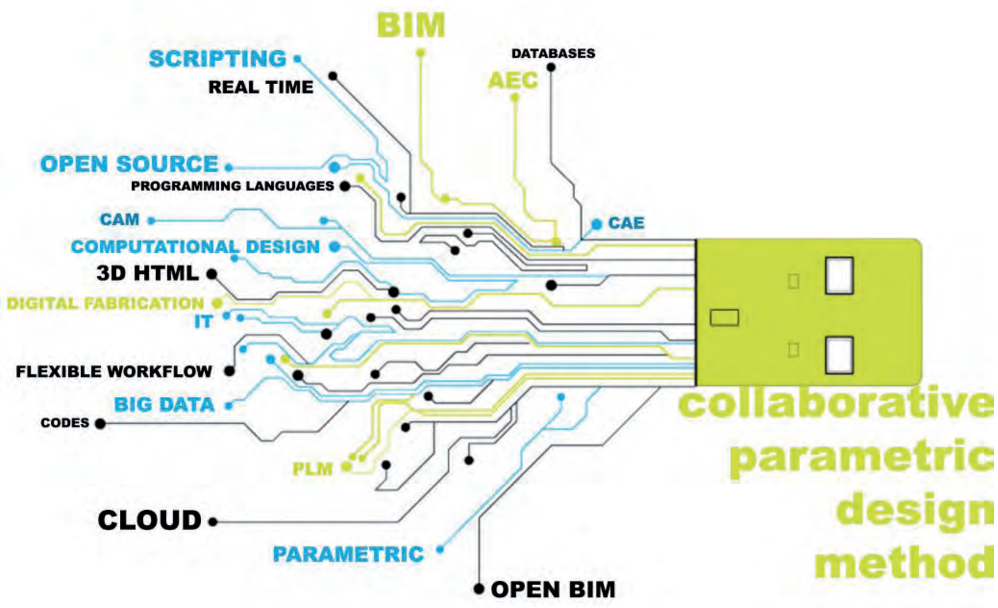

Fig. 9. A final review of collaborative parametric design method.

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[16] Ubiquitous computing (ubicomp) is a concept in software engineering and computer science where computing is made to appear anytime and everywhere. In contrast to desktop computing, ubiquitous computing can occur using any device, in any location, and in any format. A user interacts with the computer, which can exist in many different forms, including laptop computers, tablets and terminals in everyday objects such as a fridge or a pair of glasses. The underlying technologies to support ubiquitous computing include Internet, advanced middleware, operating system, mobile code, sensors, microprocessors, new I/O and user interfaces, networks, mobile protocols, location and positioning and new materials (https://en.wikipedia.org/wiki/Ubiquitous_computing).

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DECODE: REVERSE ENGINEERING ABSTRACT ART

A method for teaching computer programming for architects

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Decode is a first-level course for architects at the BTU Cottbus-Senftenberg. The goal of this course is to provide students with basic knowledge of different scripting languages. This article describes why reverse engineering modern art (from the middle of last century) is very suitable form for teaching programming and how problems can be alternatively solved using different script languages, or with graphical algorithm editors like Grasshopper for Rhino.

From 1955 until now, a number of artists have experimented with generating fine art with the help of a computer. Some of them (Georg Nees) explicitly use machine code, whereas others build analog drawing machines (Jean Tinguely), or simply use code-like descriptive methods (Sol Le Witt) for their art. In the 1970s op-art emerged that involved using patterns with optical illusion effects. In this course a number of art works from 1960s until end of 1970s were reprogrammed as their main formal creation methods are repetition, recursivity and iteration.

After an analysis and “reengineering” of existing artwork, students develop their own designs using the methods learned and, furthermore, go on to produce/draw these on a table-sized computer numerical controlled (CNC) mill. This way, not only do students learn about basic computer scripting but also how their codes can be directly processed by a computer-controlled machine.

INTRODUCTION

Art and technology have developed concurrently throughout history. Soon after computers were installed in major institutes worldwide in the mid-1960s, we can observe the surge of artists eager to generate art using a computer. Shortly thereafter, the first computer aided design (CAD) systems for architects were developed. [1]

The term ‘decode’ describes the interpretation and conversion of symbols from their coded to their original form, and is a process mainly used in informational technologies for communication or visualisation tasks. In the context of this course, we consider artwork as coded work. That is, the process of formal dissection is done by analysing the principles of the formal structure of the original work. With the help of computer languages, the observed works of art are experimentally rebuilt.

When we observe the average architectural work environment, we find that programming skills are not essential for doing the job. For normal designing, technical or communication tasks, an architect will not need any scripting/programming knowledge: most tasks can be achieved using commercially available or free software tools.

Until a few years ago, the barriers to developing an independently programmed tool were quite high in terms of platforms, program language and incorporation into a working system. In the last few years, these barriers have been reduced, with a shift towards software development in design and technique programmed not by software engineers but by architects. There are several reasons for this: new innovative software instruments are simplifying the act of coding; online learning and exchanging platforms are increasing the speed of getting the ‘how to’ information; and the transition of big universal programs to small hand tailored applications for specific needs.

As this ongoing process is inevitable, the methods of professionalising programming skills of architects is an important step towards better functioning architectural or office applications (efficiency, usability, maintainability, dependability and reusability). [2] Furthermore, with a different motivation to the subject of work between architects and software engineers, there might also be an alternative teaching method more fitting for architectural needs.

RELATED WORK

Both this article and the course are built upon artwork from the 1950s to the 1980s. Most art references come from the traditional abstract and experimental computer art era. The generic and parametric structure of minimalism, conceptual or op-art provides a good basis for digital decoding. Conceptual and formal similarities can be found between these different art movements despite their artistic deviation. [3]

Code-like abstract art of Sol Le Witt's Wall Drawings are the best example of how explicit written instructions can produce form in a conceptual manner. Coding experiments to reconstruct his text-instructions are still very popular in current computer-art and interdisciplinary design courses. Casey Reas, one of the developers of the programming language *Processing*, describes that his main motivation for the development of a new programming language was the work of Sol Le Witt and the lack of programming instruments available for making intuitive formal solutions. [4] *Processing* is now a wide spread programming tool that is predominantly used by artists and those in other graphics-oriented disciplines. With a wide library of additional software add-ons is also used as a tool for any kind of media art.

The main collection of computer art is done by the 'recode project' (www.recodeproject.com), with a platform for a community-organised collection of mainly computer art from the 1960s to the 1980s. This collection contains a large library of artwork where some of the work is decoded in processing language. It also holds a link collection for the magazine, *Computer Graphics and Art*, which was published quarterly between 1976 and 1978 by Berkeley Enterprises Inc. and focused on art experimentation around computer graphics, including essays on electronic art. Although the recode project does not containing a significant code collection, it still gives a good overview of computer art in the specific period.

A significant collection of articles and examples of computer art is done by Translab in the 'Burundi Datalab Project' from Slovakia. This is an interdisciplinary research project to study the history of new media and contains a commented list and articles of artists and artwork from several decades of the second half of the 20th century (translab.burundi.sk).

GOALS AND CONTRIBUTIONS

(1) New method of teaching programming for architectural students

The main motivation for the course is the development of a fresh approach to teaching architecture students about computer programming. One question is how students of architecture, with no coding experience, solve design problems using basic programming techniques.

(2) Resolving abstract art through code as a driving force for learning programming

Architects commonly work with visual elements, particularly when they explain their designs or try to describe complex content. Abstract art seems an appropriate graphic equivalent to common coding examples, where programming basics can be explained step-by-step.

(3) New code solutions for several art work from the minimalism, op-art and conceptual art period

The course examines existing codes for art pieces and further develops and optimises them. As students are also working with art that was never decoded yet, new code is being produced. This code will be published on the 'recode project' webpage to share this knowledge.

HISTORICAL OVERVIEW

Art is always connected to its embodied code. When we look at art, we tend to find the 'deeper meaning' of the studied object. With the surge of abstract art one hundred years ago we can observe a switch from figurative narration to non-story-telling geometry and colour compositions. Even if the large part of abstract painted art is two dimensional, we can still often see the spatial components in most of them; for example, Malewitsch's main work, where objects float and overlap in space. Although the intuitive working process of some artists from first part of the 20th century, that makes decoding a bit more difficult, has been replaced by more calculative art. Abstract expressionism as a non-geometrical art movement lives from the intuitive movement of the artist arm. It seems that the intuitive working process in abstract art fades away towards the 1960s, especially with the new conceptualist and minimalist art thinking. Conceptualism as an art movement, contrary to the digital art of the 60s and 70s, focuses on concept rather than output; that is, its own code. Similar to digital art, where the terms ‘original’ and ‘copy’ are being questioned, it supports the paradigm shift in the way that the original materialised work is set to background: this is the only similarity to digital art. Digital art has evolved from form-finding experiments with new computational methods and is still very heterogeneous, without one overall conceptual foundation. Computer art prepared the groundwork for the impending media art movement.

DIDACTICAL APPROACH

This course comprises four parts:

(1) Weekly lecture in processing

Programming lectures in the first two months with exercises and homework. As most of the students do not have any previous programming experience and do not have common operating systems, a programming platform solution is to be finalised. Processing, developed by Ben Fry and Casey Reas at MIT in 2001, is considered a perfect platform that unifies a simple IDE (integrated design environment), simple command structure based on java and C++, has good graphical output abilities and most programming routines can be done in *Processing*. The course programme is developed together with software engineer, Ramin Soleymani.

(2) Decoding exercise of an existing art work

Parallel to the intensive input at the beginning of the course, students choose their work from a list of artists (Mohr, Nees, LeWitt, Molnar, Vasarely, Malewitsch, Lisitsky, Andrade, Riley, Zajec, Bangert, Basset). The goal is to decode the artwork as well as explore the chosen artist’s context and summarise the structural principles. The produced code gives a graphic twin that should follow these principles without making an exact copy of the original work (fig. 1-2).

Hand-schemes are essential for finding out the main principles of the observed art piece. After discovering programmable regularities in the observed work, an appropriate programming principle is suggested. In addition to the individual working with code concepts, this part of art work reverse engineering crucial to understanding how complex systems can be reduced to simpler ones (see fig. 3.). The degree of difficulty varies among art pieces. Artwork with an obviously digital background (Nees) is more easily comprehensible in reengineering. Abstract art without explicit digital context are particularly hard to decode (Vasarely).

Fig. 1. Open incomplete cubes (by Sol le Witt, 1974). [5]

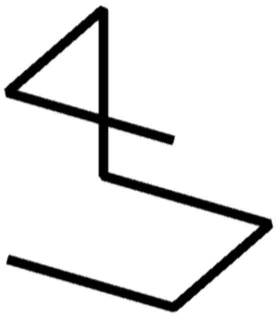

Fig. 2. Decoded version, one from a series, open incomplete cubes.

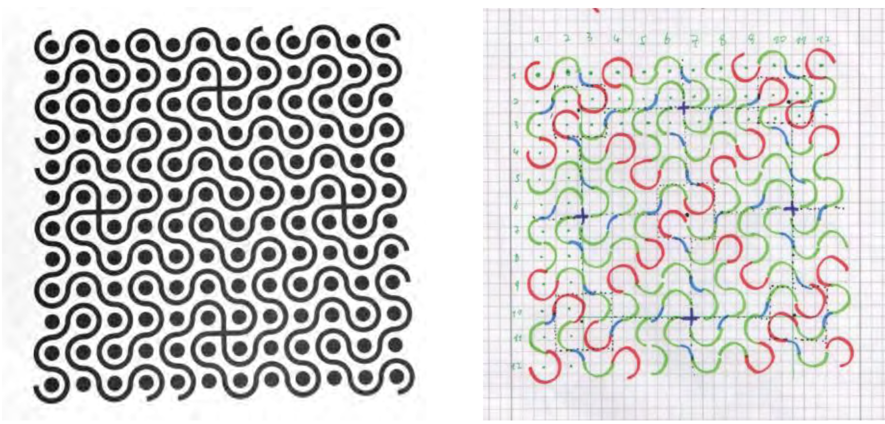

Fig. 3. Black Dragons (by Edna Andrade, left) and Hand-sketch (by student Bing Ding, right).

(3) Individual work – code part

Applying the knowledge gained from the earlier course parts, students develop their own digital art code. Their individual work is mainly based on code and principles from the decoding process. As the drawings are processed with a CNC-machine it is important to consider the output format and its constraints. Finally, two parameters are important when processing the image:

1. The drawing will contain only lines. Filed areas should be minimised and pen-behaviour examined (jittering),

2. Inaccuracy from the pan attached to the CNC-machine is to be considered. Uncertain output can be the part of the work.

(4) Individual work – paper part

Prior the CNC-drawing process, each participant learns the basics of exporting the art work in a pdf-drawing, importing the pdf-drawing to rhino-CAM, making the machine-paths, exporting the nc-file to the CNC-controlling-unit and, finally, controlling the machine-drawing process. As all work is done individually, all participants go through the whole production process.

OUTCOME

Beside the decoding significant art work and individual coded CNC-machine drawings the important output of the work is the book, *Decoded Art - a Programming Handbook for Architects and Designers* (see fig. 4) This book contains comparable code examples for different programming languages: Processing, VBScript, Python and Grasshopper for Rhino 3D. Most examples come from the programming part of the course, the optimised programming outcomes of the students (Processing) and additional comparative examples (VBScript, Python, Grasshopper). Focusing only on one single programming language can limit one's view when working with complex formal systems, particularly if they are interactive. To demonstrate alternative approach methods in task dependency it is important to recognise programming language differences. With the rising popularity of Grasshopper, a graphic algorithm editor, it is also important to demonstrate the weaknesses and strengths of graphical- and script-orientated methods. The main goal of the book is to provide the reader with basic knowledge in programming techniques that will help them solve tasks independently of the programming/modelling surrounding.

Fig. 4. Decode Art – Programming Handbook.

NEXT STEPS AND CONCLUSION

Post-course evaluations show that the decoding part of the course was the most demanding (75% of the students declare that it was difficult). Over 40% of the participants are interested in continuing the course towards programming 3D models. Considering the evaluations, some improvements must be made in upcoming courses; for example, simplifying the examples, and reducing and concentrating on basic scripting principles. With the upcoming second part of the course 'Decode Sculptures' in programming 3D, forms an advanced course for participants with basic scripting knowledge will be offered.

Working with art analogies can be a push method for delivering programming abilities to students with no programming experience. Quick visualisation results as programming output gives a much better non-abstract approach to this complex topic. This, combined with formal decomposition and reengineering of existing artwork in a programming manner, is demanding but can give the participant the basic understanding of how software systems are structured and motivate them for further investigations in computational methods in architecture.

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GAME PATTERNS IN INTERACTIVE ARCHITECTURE

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The history of architecture, and movements such as modernism, brutalism, or post-modernism, showed that the type of the system might differentiated the quality and model of space. This research is about interactive architecture within the patterns of the systems in various games. In games, there are several types such as classical board games, gambling games, digital games, or multiplayer games. Each of them is based on specific system, rules, design and interactivity. As in architecture, so in games the significant characteristic is the system which is a set of things describing the whole surrounding and interactions between human and built environment.

But how can architects design future places of interactive architecture principled by the traits of games? To answer that research question, several game environments were analysed, such as digital games (SimCity), board games (Game of Thrones), ludic games (Hide and seek), and games with strongly environmental attributes as Maze. Moreover, the methodology of framing the system in games was implemented in analyses of realisations of Interactive Architecture (iA). The results of research highlighted the utility of using the games' system methodology in Interactive Architecture as a medium for better understanding the aspect of interactions between human and built environment.

ARCHITECTURE AS A SYSTEM

Various types of architecture movements (The Renaissance, modernist, Brutalist) in architecture - various types of space for its users. In this research, the history of architectural movements are not the direct issue, but it is important to notice the range of solutions for space. One of the notable architects - Le Corbusier wrote: “The house is a machine for living in”. [1] His realisations (Villa Savoye, Unité d'Habitation, or Sainte Marie de La Tourette) showed the novel way of designing houses, where specific plan of rooms let users to live in more healthy, comfortable and systematic manner. Mies van der Rohe manifasto "Less is more" [2] caused that his buildings (Villa Tugendhat, Neue Nationalgalerie, or Seagram Building) had simple forms where quantity of types of material and geometry were limited in order to achieve persuasive simple expression of tectonic. The other important modernist creator and the principal member of the De Stijl was Gerrit Rietveld. His project Rietveld Schroder House is the quintessence of connection of architectural vertical and horizontal elements shaping the whole space as the flexible surrounding without hierarchical arrangement of rooms in the floor plan. The manner of forming the space as the built environment which influence its user not by ornamentation, but rather by the game of architectural elements such as walls, ceilings, floors and furniture was followed also by contemporary architects. Bernard Tschumi in his theoretical project "The Manhattan Transcripts" stated that the architecture is the space of elements which stimulate human actions and the amount of various events in built environment. [3] His research was later transferred into his projects such as Parc de la Villette, Alésia Museum and Archaeological Park, or Paris Zoological Park. In the middle of 20th century polish architects Oskar Hansen and Zofia Garlińska-Hansen established the theory and conception of Open Form which means: "(...) shaping the cognitive space, which is construed as a background highlighting the ever-changing events in the life of nature and of man". This idea and the concept of the Linear Continuous System (LSC) was included in their design of two housing estates in Warsaw: "Osiedle Słowackiego"(1961) and "Przyczółek Grochowski" (1963). The Linear system were used to intersect the residential zone with industry and nature by service in order to eliminate the centre and the periphery. [4]

Interactive Architecture (iA) as a philosophy of the space as an open loop of actions, events and motion is developed since 20th century as well as the cybernetics, electronics, computers and Internet. One of the first project "The Fun Palace", design by Cedric Price, set the new way of shaping space. It was the building where "the only fixed element (...) was to be the structural grid of steel lattice columns and beams. All other programmatic elements – hanging theatres, activity spaces, cinema screens and speakers – were to be movable or composed of prefabricated modular units that could be quickly assembled and taken apart as needed." [5] Moreover, the project contained the various spatial scenarios established with an English cybernetician Gordon Pask. This significant project was never built, but it started the novel way of thinking about the building, not as the Vitruvius' statement of firmitatis (stability), but rather fumositate (changeable). Thus, in iA the "volatility" exceeded "stability" and the man became the "creator" - not "user". The idea of interactivity taken from the virtual world characterized the architecture as a space of infinite possibilities. Nowadays, the progress of electronics and innovative materials accelerates the development of Interactive Architecture, continuing the fundamental patterns of space variation, affecting the senses, perception and imagination of men. Because of the interactivity is the essential feature of the world of games, and games are inherent element of human life, Interactive Architecture is compared and analysed in this paper with their basic element - the system which differentiates the types of architecture within them. Therefore, the fundamental questions in this research refer to the system in games and run as follows:

What are the parameters of the system in games? What are the parameters of a space in games?

What are the parameters of the system in Interactive Environment referring to the system in games?

How to design Interactive Environment? How interactivity in games is connected with interactivity in architecture?

GAMES AS A SYSTEM

The history of development of games is as wide and expanded as evolution of architecture. Over the years, various types of games were born, such as classical board games, gambling games, digital games, professional sports, multiplayer games and many others. From theoretical point of view, the game may be described as "a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome." [6] This definition written by K. Salen Tekinbas and E. Zimmerman focused on six elements of the game: system, player, artificial, conflict, rules, and quantifiable outcome. In this section, the concept of space and spatiality regard to system of the games is investigated.

What is "a system", and what is its relationship to games? There is not one comprehensive explanation of the system. Moreover, it is varied depending on the field of science and situations. According to the Oxford Dictionaries, the general definition of the system is "a set of things working together as parts of mechanism or an interconnecting network; a complex whole" [7] In the context of games it means that each particular element - player, rules, or visual appearance - is a part of bigger structure which combines them together. Game designers and researchers provided the large number of definitions of game as the system. One of a notable creator Chris Crawford highlighted that the game is "a closed formal system that subjectively represents a subset of reality." [8] His point of view stressed that through the set system the game is self-sufficient environment which does not need agents from outside to be alive. On the other hand, scientists E. Avedon and B. Sutton-Smith defined the game as "an exercise of voluntary control systems, in which there is a contest between powers, confined by rules in order to produce a disequilibrial outcome." [9] This explanation highlighted that the system is a set of various forms of activities. Moreover, the system in games was considered as "narrative systems that communicate story information" [10] which means that the environment is treated as a place of various events scenarios.

One of the description of the system is that it provides various types and quantity of interactions between artificial elements and human body. Depending of the range and model, the different series of events might happened. Moreover, each game can by classified by various methodologies of framing the system. One of the methods, proposed by K. Salen Tekinbas and E. Zimmerman, focused on "The Elements of the System" [6] which analysed system in four aspects: objects, attributes, internal relationships, and environment. The objects mean the parts, elements, or variables within the system. The attributes described the qualities or properties of the system and its objects. The internal relationships characterised the relations among the objects. The last element - the environment is interaction which is affected by its surrounding. These methodologies can be used in the context of formal system (a strategic and logical system), an experiential system (to see interaction between the players and the game), or as a cultural system (to see connections between time and space). In this research, the first approach "the formal system" was used.

The analyses of four types of games were made in "The elements of The System" method. The games such as ludic game (Hide-and-Seek, see fig. 1), board game (Game of Thrones, see fig. 2), puzzles (Maze, see fig. 3), and digital game (Sim City, see fig. 4) were taken in this investigation.

Fig. 1. LUDIC GAME | Hide-and-Seek (by Eden, Janine and Jim). [11]

The Elements of a System:

1. Objects: participants and elements of the built surrounding.
2. Attributes: rules are defined ad hoc.
3. Internal Relationships: elements of the surrounding might determine strategic correlations.
4. Environment: interaction between participants emerged from the play

The analyses of the Hide-and-Seek showed that architecture (objects) of this game is composed of built surrounding and human body. In this case there is no play without human, because the attributes (rules) are not defined, and only human body could fully fill the game - there are no actions between artificial elements - man defines the rules ad hoc and choose the elements of the built surrounding. This situation caused that internal relationships are not fixed - it means it might be changed through the spatial properties of the place which determine the strategic correlations between objects. Moreover, the environment emerged during the play and were depended the movements of players.

Fig. 2. BOARD GAME | Game of Thrones (by François Philipp). [12]

The Elements of a System:

1. Objects: the pieces on the board and the board itself.
2. Attributes: rules are defined.
3. Internal Relationships: the actual positions of the pieces on the board.
4. Environment: interaction of the objects is the play of the game itself.

In the game "Game of Thrones" the architecture (objects) of this game is built of the artificial elements: pieces on the board and the board itself. The human is not the part of the architecture of this game in the context of "formal system". It means that the position of pieces on the board is the game itself. Moreover, the rules are defined, so we could predict the steps of the game. Internal relationships perform between the relations of elements on the board - one piece might be defeated by another one, or gain an empty area. Because, the play is only between artificial elements, the interaction between them is the play.

Fig. 3. PUZZLE | Maze (by Seongbin Im). [13]

The Elements of a System

1. Objects: elements of the built surrounding.
2. Attributes: rules are defined but they are modifiable.
3. Internal Relationships: the actual positions of the partitions.
4. Environment: interaction of the objects is the play of the game itself.

The game Maze is the example of puzzle game. The architecture (objects) of this game is composed only of the built surrounding, without human body. In this case the play might happen without human because the types of elements of the maze are the only objects. The architecture of the maze is solid and static. The rules might be modifiable because there are no fixed time, not one path to solve the game, and no fixed starting or end point. Internal relationships are only between the elements of the maze - the size of the walls, the distance between the walls, and the length of the paths. The environment shows that the interaction between objects activate the play.

Fig. 4. DIGITAL GAME | Sim City (by haljackey). [14]

The Elements of a System:

1. Objects: abstract built environment (buildings, roads).
2. Attributes: borders are defined, buildings quantity are limited.
3. Internal Relationships: the actual positions of the objects.
4. Environment: interaction of the objects is the play of the game itself.

The objects are only artificial digital elements such as roads, buildings, trees, and others. The attributes are strictly defined, as well as the spatial connotations between particular elements such as types of buildings. Internal relationships perform only between positions of the objects, and influence the environment which is reflected in the type and spectrum of interactions.

THE GAME SYSTEMS IN INTERACTIVE ARCHITECTURE

The method of „The Elements of a System" was used to understand the system in Interactive Architecture. The two projects were analysed: Sonic Forest (author: Christopher Janney / New York 2014) and Interactive Fingers (author: LAX laboratory for architectural experiments / Wrocław 2014) (see fig. 5).

Fig. 5. iA | Sonic Forest (left) and Interactive Fingers (right).

The Elements of a System:

1. Objects: participants and elements of the built surrounding.
2. Attributes: rules are partly defined.
3. Internal Relationships: elements of the surrounding might determine strategic correlations.
4. Environment: interaction of the objects is the play of the game itself.

The objects in both projects are similar to the game Hide-and Seek, and consisted of built surrounding and human body. The only difference is that the rules are partly defined. It means that particular elements of built environment might be activated merely by human actions following the established movements (for example: hand touch the hole - the sound effect is activated / leg touch the hole - the board is moved). Without following that rules the interactions between objects are not completed. This assumptions made that internal relationships are modifiable and might influence the strategic correlations between objects. Moreover the environment emerged during the play depends of the actions of players.

The research aimed to show that using the method of framing the system in games might be useful to understand the built environment in Interactive Architecture. Moreover, this approach can help architects to visualise the relationship between human and artificial elements in process of interactivity as a new feature of surrounding. Moreover, K. Salen Tekinbas and E. Zimmerman suggested that "the systems that game designers create have many peculiar qualities, but one of the most prominent is that they are interactive, that they require direct participation in the form of play." [5] - it highlights that there is a great similarity between the game world and the world of Interactive Architecture. This possibility of implementation of the methods from games into iA might increase the awareness of architects in the process of designing the interactive environment as the multi-complex systems of interactions.

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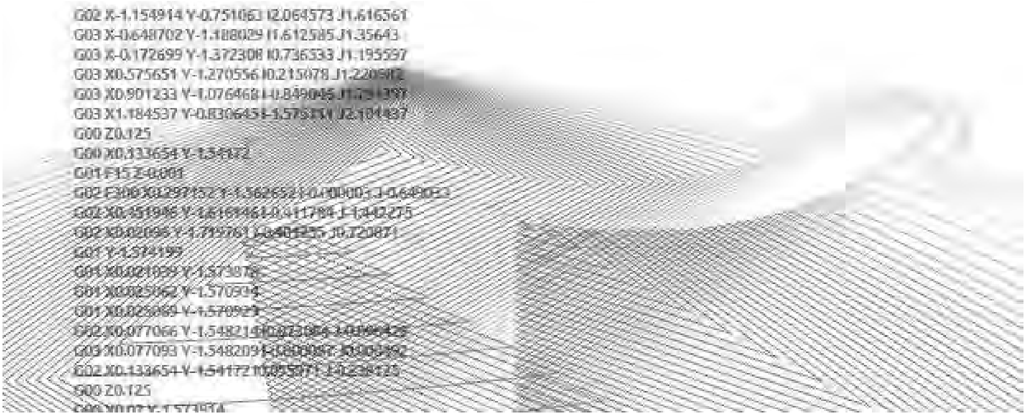

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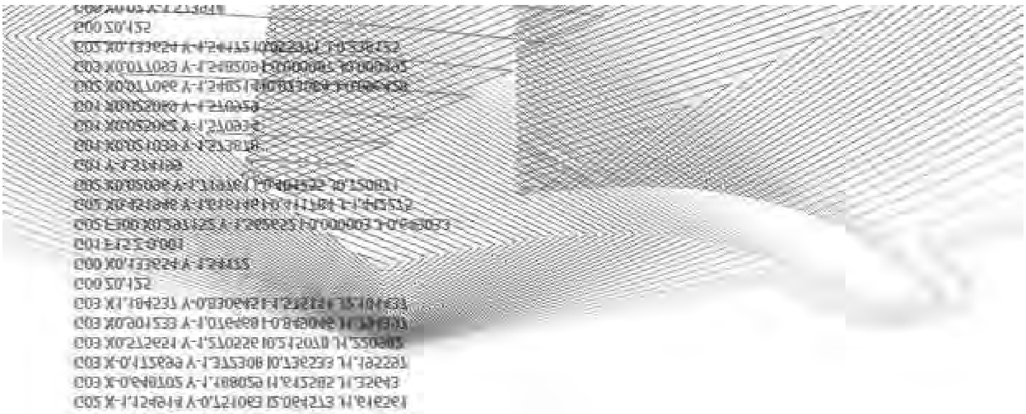

BIOMIMICRY
D_esign from N_ature to A_rchitecture

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The purpose of the study research should develop a first approach into the world of biomimicry by examining the ways of its application and the ability to develop sustainable design. Furthermore it should try to answer the question whether the use of biomimicry can create or not a new architectural style.

At the first part is analysed the etymology of the notion of biomimicry and the differences between the term of 'biomimicry' and other terms encountered in the bibliography as synonyms or identical. Thereafter, a historical report studies the origins of biomimicry and its influence to the design process over the years.

Finally, a study on the objectives, the principles and the methods of biomimicry provides a means for understanding the role of biomimicry in the design process.

INTRODUCTION

Building first evolved out of the dynamics of basic needs for shelter, security and the disposal of natural means such as wood, stones, etc. As human cultures developed, needs were multiply as well as the demand for means. In order to satisfy those needs people started to use more and more the natural resources available without calculating the impact of the ecological footprint of this action. Over the years, especially during the 19th and 20th century, this process has created many environmental problems. Nowadays, we face a major environmental crisis that it could compromises the lifestyle and in general the future of human kind. It is our responsibility to deal with those problems so we can deliver a better world to the future generations.

At first we need to understand that mankind is part of an ecosystem. Secondly we must follow the principles of this ecosystem in order to preserve our environment and ensure our survival. Other organisms (part of the ecosystem) have created multiple mechanisms to face the same problematics. At this point, biomimicry enters the world of architecture as a “tool” in order to apply the principles of nature by imitating the function of its mechanisms.

The application of biological characteristics of the environment can lead to the development of a sustainable design and eventually can create a new architectural style.

ETYMOLOGY

Etymologically Biomimicry originates from two Greek words:

βίος (bios) = life

the condition that distinguishes organisms from inorganic objects and dead organisms, being manifested by growth through metabolism, reproduction, and the power of adaptation to environment through changes originating internally;

μίμησις (mīmēsis) = imitation

the act of (trying to) being, behaving or looking the same as (a person etc). [1]

TERMINOLOGY

In the general bibliography researchers and scientists use different terms as synonymous or identical referring to biomimicry. However, the differences between them are so fundamental regarding the goal and the process of each method that we should distinguish them as follow:

In **“biomimicry”** the goal is to ensure the triangle of sustainable development: economy-society-environment.

In **“biomimetic”,** in order to achieve the final goal, sometimes we can abuse one or more of the parameters of the triptych.

In **“bionic”** we study nature for ideas that stimulate independent technology research.

"Biomorphism" uses as design patterns natural forms and principles that only imitate the image of nature. On the other hand Biomimicry imitates the form and the technical characteristics.

Finally, **"Bio–utilization"** refers to the direct use of nature and "bio–assistant" is the domestication of living organisms. On the contrary biomimicry studies the functionalities of living organism to reproduce them artificially.

HISTORY REVIEW

Biomimicry finds its origins well before the establishment of the actual term. Over the years many people managed to change the course of history using nature as a source of inspiration. The work of Leonardo Da Vinci [2] is one of the most important examples in human history. During the Renaissance period he designed several machines by observing and studying living organisms. His work became an inspiration for others to create several machines that today represent our civilization, like the brother Wrights who build the flying machine [3], etc. (fig. 1). Despite all that, the term of biomimicry is established in 1962 by Rachel Carson and the field of biomimicry is delineated in 1997 by Janine M. Benyus.

Fig. 1. Leonardo Da Vinci flying machine (left, by L. Da Vinci)
and Brother Wrights' flying machine (right, surclaro.com). [4][5]

DEFINITIONS

Several definitions have been appeared since the establishment of this discipline. For example Janine Benyus defines the term of biomimicry in three aspects in accordance to the role of nature:

1. **Nature as a model.** Biomimicry is a science that studies nature's models and then imitates or gets inspired from these designs and processes to solve human problems, e.g., a solar cell inspired by a leaf.

2. **Nature as measure.** Biomimicry uses an ecological standard to judge the "rightness" of our innovations. After 3.8 billion years of evolution, nature has learned: what works, what is appropriated and what lasts.

3. **Nature as a mentor.** Biomimicry is a new way of viewing and valuing nature. It introduces an era based not on what we can extract from the natural world, but on what we can learn from it. [2]

Five years later Janine Benyus redefines the definition of biomimicry as a design principle that seeks sustainable solutions to human problems by consulting and emulating nature's time-tested patterns and strategies. [6]

Michael Pawlyn defines the area of biomimicry as "mimicking the functional basis of biological forms, processes and systems to produce sustainable solutions". [7]

Finally D. Dollens defines biomimicry as the search for and implementation of extractable processes and/or qualities from nature providing science and engineering with models for chemical, medical, and structural research. In an architectural context, biomimetic is an investigative process for evolving and/or mimicking methods in order to extract ideas, processes, attributes, forms, textures, spatial relationships, and sometimes life characteristics for example, phototropism. [3][8]

OBJECTIVES – RELATION OF BIOMIMICRY WITH ARCHITECTURE

The general objective of biomimicry is the achievement of viability. Because biomimicry is used in different disciplines, such as architecture, biology, etc. the meaning of viability depends on the scientific area that is introduced. However, all versions are placed in an overall context where biomimicry is a practical method which studies nature to find solutions to various problems.

By using this method we are entering a new era where we are not rely on what we can extract from the living organisms and the ecosystems, but on what we can learn from them.

However, we should establish the type of relationship between living organisms and architecture and what biomimicry can brink in the architecture field.

Living organisms and architecture share common goals. Both are adapting to the environmental changes so they can ensure their survival. In nature, the accomplishment of those goals is achieved through several processes and concepts that architecture may use as a background and inspiration to create innovative solutions to specific problems. Biomimicry has thirteen major design principles that they are exclusively inspired by nature's "operating system".

In general all the principles concern the reduction of consumption of energy and resources, for example recycling, development of effective energy strategies etc. Simultaneously they introduce some design frameworks that they maximize the flexibility and the features of the results, for example organization with fractals, self - assembly, etc.

There are three main levels of biomimicry and five sublevels depending on the features that are imitated:

1. Organism: Imitation of the function of an entire organism or a part of it.

2. Behaviour: this refers to mimicking a specific type of behaviour or act that the organism does to survive or replicates on a daily basis in relation to a larger context.

3. Ecosystem: this refers to mimicking a specific ecosystem and its functions as well as what elements and principles are required for it to function successfully.

The five dimensions of biomimicry are:

Form, Material, Construction, Structure, Function. [9]

It is necessary to define in advance the level of imitation in order to achieve the desirable design result. This is because every next level is not depending on the study, but on the elements of an organism or an ecosystem that is imitated.

WAYS OF APPLICATION OF BIOMIMICRY

There are two ways of apply the principles of biomimicry. The first method is from nature to design and there are 6 steps for its application (fig. 2). [10]

1. Discovery: A physical model is selected to study its survival mode, the principles and strategies followed in order to survive in the environment.

2. Abstract: The basic concepts of design and the identification of the repeated patterns are achieved through a process of abstraction.

3. Brainstorm: Suggestions for possible applications of these standards and principles.

4. Imitation: Development of models in which the strategies of nature are applied.

5. Evaluation: Evaluation of solutions in relation to the principles of life. The capabilities of the model are put in question.

6. Determination: Repetition of the procedures in order to resolve the problems created during evaluation.

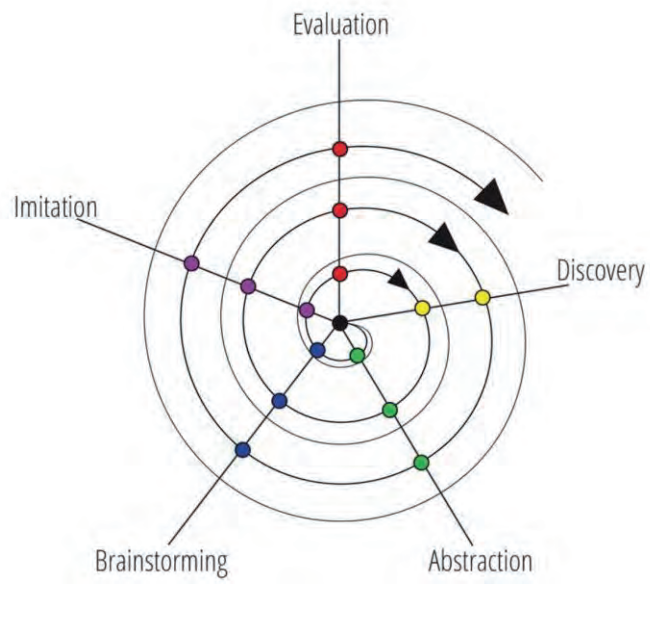

Fig. 2. From nature to design.

The second method is from design to nature and there are 7 steps for its application (fig. 3) [7]:

1. Determination: A sort project of human needs/problem is developed.

2. Interpretation: The designer turns to nature and looks for how the nature solves the problem and what are the elements that are avoided in order defining the environmental conditions.

3. Discovery: Biological models that are using brief design are discovered and then selected those that survival depends on resolving this problem.

4. Summary: The basic concepts of design and the identification of the repeated patterns are achieved through a process of abstraction.

5. Imitation: Development of solutions based on biological models

6. Evaluation: Evaluation of solutions in relation to the principles of life.

7. Determination: Repetition of the procedures in order to resolve the problems created during evaluation

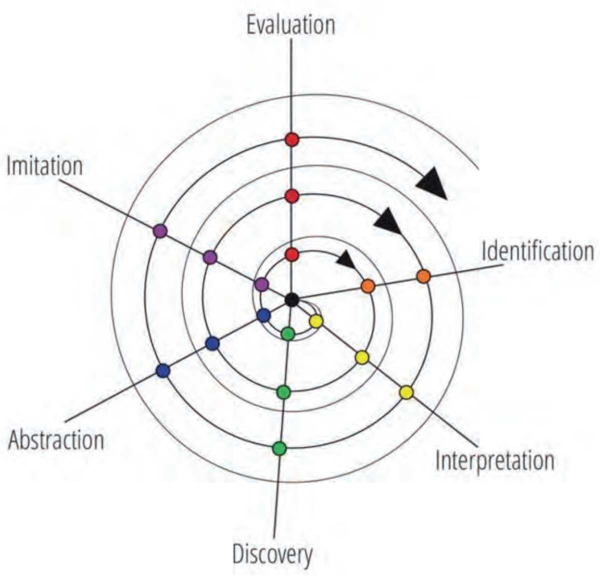

Fig. 3. From design to nature.

LINK BETWEEN BIOMIMICRY AND ARCHITECTURE

Biomimicry joins modern trends of architecture like parametric, adaptive, emergency and complex design. Those notions are already introduced in architectural design, independently of biomimicry. This is because of the influence of sociology in the field of architecture. Sociology borrows terms from biology to explain different social phenomenon.

RESULTS

The use of Biomimicry can change our lifestyle exploring possibilities for innovative architectural solutions inspired from nature. Nowadays the problematic of sustainable development has created a fertile ground for the development of biomimicry and other similar methods like bioclimatic design. Even though those methods deal with sustainable development, biomimicry uses a general approach where sustainability is not limited to the triptych of society-economy-environment. However biomimicry could be used as a tool in the application of bioclimatic design.

One question that we should answer is whether the biomimicry creates or not a new architectural style. Sometimes its application can create specific innovative forms, like in the Eden Project designed by Grimshaw [11][12], a greenhouse in Cornwall (fig. 4). In this case the design mimics the structure of unicellular organisms and carbons molecules to minimize the structural sections and maximize the transparent surface. On the other hand the example of the seawater greenhouse [13][14] in the desert of Oman designed by Charlie Paton mimics the system that the desert beetle has developed so it can harvest clean water through condensation of atmospheric moisture (fig. 5 and 6). In this case the application of biomimicry doesn't produce any specific form related to the imitation of this mechanism. Biomimicry generally doesn't create architectural designs with common morphological data. To sum up, biomimicry is a "tool" that it could never replace the role of the architect. The choice of the model to be emulated, the way that the principles are translated and then applied is an entirely personal matter and it is not defined by objective criteria.

The application of biomimicry in architecture raises another important question; is the ultimately goal of its application to create live architecture? Petra Gruber supports that architecture by definition is inorganic. However the architectural edifices have a life circle, which is a point of comparison, parallelism and connection to the living organisms. There lies biomimicry.

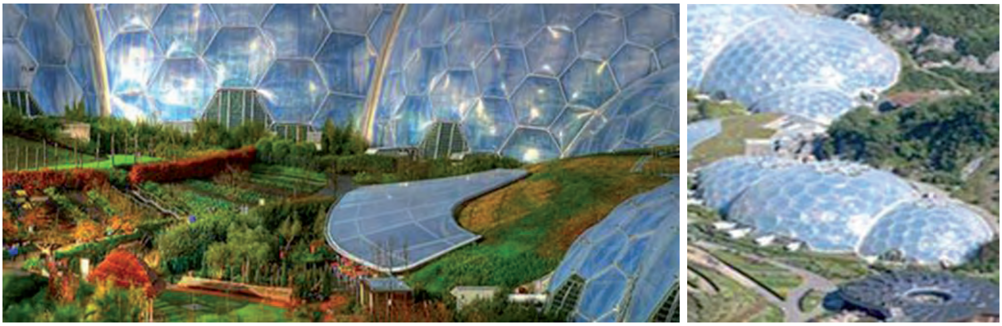

Fig. 4. Eden project by Grimshaw (by Stuart Herbert). [15][16]

Fig. 5. Greenhouse by Charlie Paton (by globalwaterforum.org). [17]

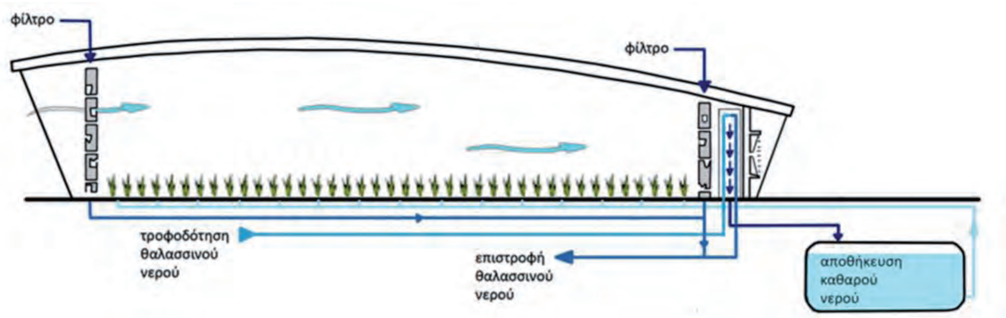

Fig. 6. Function of Greenhouse by Charlie Paton (by Karen Chernick). [18]

Despite that biomimicry can be a useful tool in architectural design, its application should be done with responsibility. The imitation of certain natural mechanisms might have the opposite effect on the environment. In nature there is no strategic planning in the long run. Living organisms develop mechanisms to ensure their survival in the present or the near future. On the other hand humanity can explore all the opportunities to achieve long-term sustainability over the years.

CONCLUSION

One of the main characteristics of nature's productions is that they need constant maintenance and / or reconstruction, like the termite's nest [19]. This cannot be emulated in the construction of a building, but it could be an example for a temporary structure (fig. 7).

Finally, living organisms are unable to borrow features implemented by other organisms. On the other hand human kind is in a privilege position because we can adopt the design features from one or more organisms to create complex combinations and more efficient solutions.

Fig. 7. Termite's nest (by tumblr.com). [20]

However there is a new problematic created whether we can intervene or not in nature. To better understand we can take the example of Dune Arenaceous which is an example of bio-assistant using the principles of biomimicry. In this design Magnus Larsson takes advantage of the ability of the bacteria Sporosarcina pasteurii to create erosion and sedimentation in the sand producing a solid material; In that way he can create, in 24 hours, spaces in situ [21] in the desert that they can develop habitable temperature with a potential to develop flora within a decade [22][23]. The final goal of the project is to create a stripe along Africa, which will stop the desertification of the continent. Dune Arenaceous intervenes in an already devastated region, which is not the result of human activity, to create suitable conditions of habitation (fig. 8). Theoretically this gives us a viable solution. On the other hand we can cause a violent climate change that can imbalance the local ecosystem. That's why during the design process we should establish a research stage so we can evaluate the impact of collateral consequences that could arise due to these interventions.

For this reason we should apply biomimicry with responsibility and criticism. Finally, as Benyus says, “we must honour with humility the limits of nature and the mystery that lies beyond it. We should admit that there are some things that exceed all of our powers.” [24]

Fig. 8. Dune: Arenaceous Anti-Desertification Architecture: 1st step (top left), 2nd step (top right), 3rd step (bottom) (by Magnus Larsson). [25]

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MORPHOGENESIS OF STRUCTURE

Cluster at the Shapes of Logic workshop

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Thanks to the current development of the algorithmic tools it is easy and convenient to pursue advanced simulation techniques and iterative processes in general. Two basic notions became the omnipresent foundation of the workshop design explorations: emergence and bottom-up autonomy. It is the nature of the iterative processes to repetitively perform the same actions on a set of data output from the previous repetition. When the actions in each iteration are dependent on the current state of the processed data or the environment and thus become unpredictable, the emergence occurs. Such a process then qualifies as non-linear and from its nature achievable only with numerical solving, opposed to an analytic approach.

The bio-inspired algorithms appear to be the most appealing non-linear systems for architects and designers to implement in the creative process. There are two distinct types of these algorithms: the biomimetic (resembling living nature in appearance) and biologically morphogenetic (resembling living nature in the growth principles). Whereas the biomimetic creations search for processes leading to a desired biological form, the morphogenesis inspires from the forces and processes generating the form regardless of its final appearance. The genetic forces are either endogenous - internal, stemming from the properties and states of the object of creation itself, or exogenous - those that come from the environment or interaction with other factors in the system.

The workshop exercises were aiming to demonstrate the main principles of bio-inspired morphogenetic processes, emergent design, non-linear growth and bottom-up systems in general - in theory, geometrical implementation, and design assignment as well as in physical fabrication. The participants were introduced to cellular automata, multi-agent systems, swarms and growth aggregation algorithms, using the currently most accessible tool - Grasshopper [1] - equipped with iterative, simulation and advanced geometry processing libraries Anemone [2], Starling [3], Weaverbird [4], Mesh tools [5] and Boid. [6]

After a series of generic exercises of the Game of Life [7] and Boid [8] flocking, the group of participants started processing an optimized architectural frame structure provided by the Min-Max workshop cluster. The input data consisted of a geometrical structure of platforms and beams complemented with discretized structural analysis data. In the geometry, the platforms were about to be replaced by a bio-inspired morphogenetic growth structure, which will be autonomous and indifferent to the structural logic of the object, yet meaningful in the resulting performance.

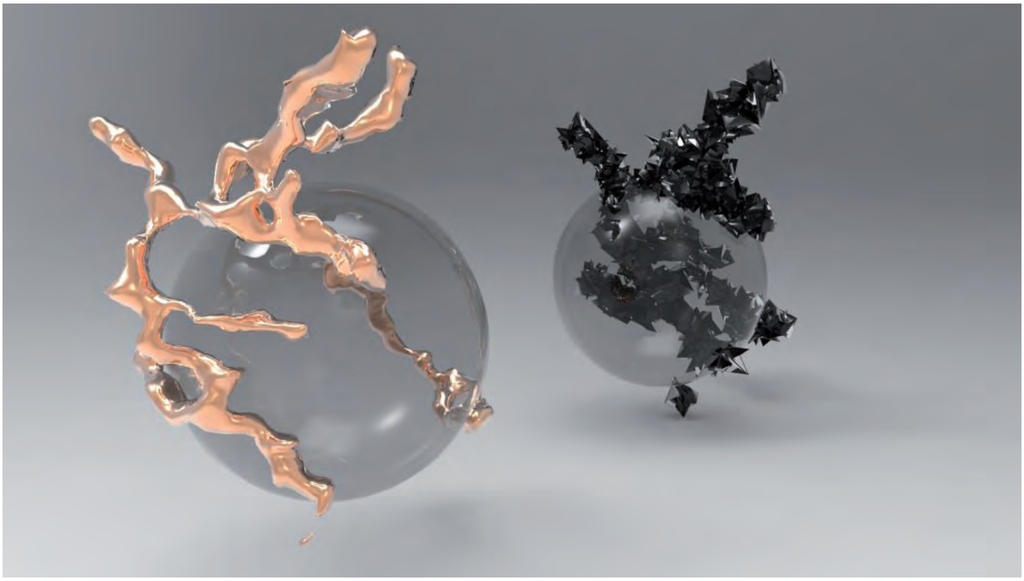

Fig. 1. Volume avoidance test (by Natalia Emilia Paszkowska).

The selected algorithm aggregates point cloud (starting from growth seeds) in the direction of the attraction points. Once the attraction point is reached, it is removed from the attractors list (is “eaten”) and the growth continues towards the remaining attraction points. The growth seeds also hold the property of age, which differentiates old fixed cells from a juvenile meristem, capable of growth. Depending on the initial distribution of the growth seeds and attraction points, the final structure takes form of a point cloud, heterogeneous branching rhizome or anything in between. Several modifications of the algorithm were made - geometry avoidance (see fig. 1), flocking behaviour of the growth direction and isosurface wrapping using the Marching Cubes [9], Laplacian [10] and Catmull-Clark [11] subdivision algorithm (see fig. 2).

This approach clearly distinguishes between the endogenous (aging, flocking) and exogenous (growth attraction) forces of an emergent generative system.

To keep the notion of autonomous growth system intact, yet supporting the structural logic of the given platform-beam frame, the system was initiated with non-random arbitrary data derived from the structural analysis of the frame. The most stressed points of each platform were used as the initial growth seeds and points distributed on the surface of the beams, gradually reaching higher density towards the platforms were selected as growth attractors. The resulting forms, while being purely self-actuated, follow the structural logic of the platforms and serve as fixed joints for the beam structure at the same time.

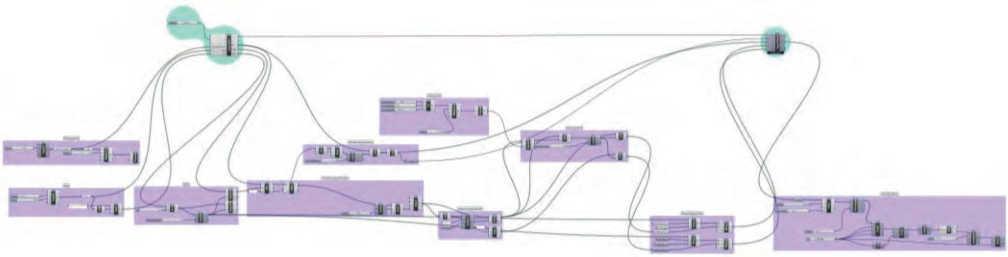

Fig. 2. Grasshopper definition (by Mariam Khademi).

The seven platforms were printed in PLA on ZMorph, HBot and Ultimaker 3d printers and assembled with 34 wooden sticks into a 60cm tall composite structure (see fig. 3). The growth was intentionally initiated (through the selection of the growth seeds and attraction points) to finally create a principally flat shape with only few joint bumps on the bottom and top. This approach significantly reduced the printing time and efficiency.

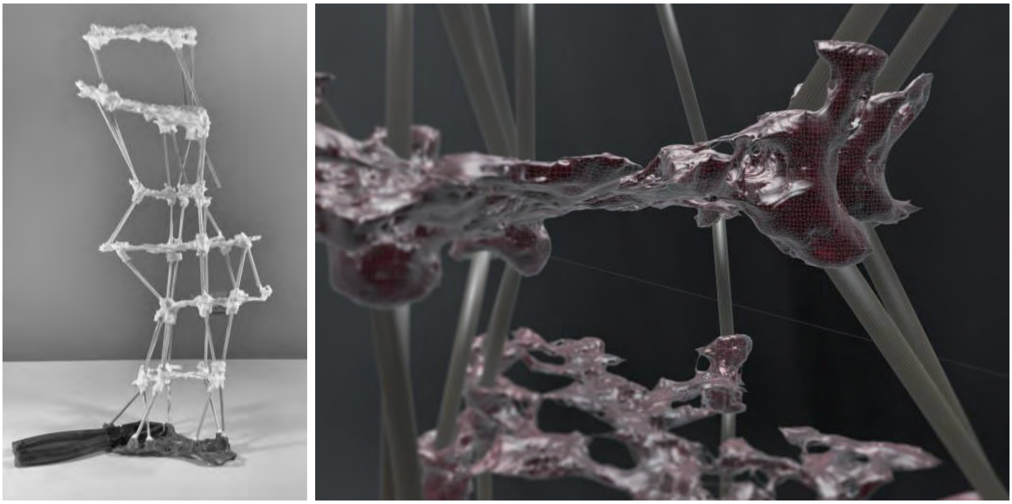

Fig. 3. 3d printed structure (left, by M. Nisztuk) and detail rendering (right, by G. Castellano).

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MULTICRITERIA OPTIMIZATION IN ARCHITECTURAL DESIGN Goal-oriented methods and computational morphogenesis

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This paper explores the concepts of multi-criteria optimization in architecture and discusses two different methodological approaches: goal-oriented techniques and methods based on computational morphogenesis. The aim of the paper is to propose potential directions for the development of multi-criteria optimization tools for architects. The applicability of both approaches and the role of architect as Decision Maker (DM) in the optimization processes are discussed. The conclusion summarizes that goal-oriented techniques, such as Evolutionary Multi-objective Optimization (EMO) Algorithms and hybrid methods, are more likely to be successfully implemented in design tools. Non-goal oriented techniques, like Compositional Pattern Producing Networks (CPPNs) and Novelty Search, although recognized as harder for direct implementation, show enormous research potential. They are promising for evolving aesthetically pleasant objects, however further work is necessary to determine whether they can contribute to the field of multi-objective optimization in architecture.

INTRODUCTION

The association between the concept of optimization and architecture apparently appeared when the architectural designs problems started to be expressed as the logical structures and functions. Christopher Alexander - mathematician and architect was the first one who proposed making ‘graph theories’ as the representation of an elaborate problem with structural framework of these graphs as a tool to produce solutions. [1] Alexander says in his book Notes of the Synthesis of Form: “at present we have no corresponding way of simplifying design problems (…), the analysis of the problem is by no means obviously possible”. [2] Since the 80's the advent of the personal computer has made it possible for individuals to apply optimization to personal projects. At the moment there are numerous software applications for architects and designers (most of them appeared after 2000 AD.), which enable graphical programming and let creators build associative geometries without coding or scripting skills. Parametric models may generate a countless number of possible answers for design problems, but it is not straightforward which of them are feasible or useful. In early design stage numerous aspects may be taken as optimization criteria from the orientation of the building on the plot, through geometry and shape to daylight availability. By working with optimization techniques, architects and designers can far more easily go through the decision-making process and achieve optimal designs.

However as Keough and Benjamin (2010) underline “the challenge of the architect is to create a high-performing building design that is the result of often competing objectives”. [3] In order to balance contradicting objectives multi-criteria optimization approaches are introduced. Nonetheless in architectural design they form a field of ongoing research. The existing tools (e.g. Octopus (2013), Optimo (2014)) still need more extensive tests and validation, as they were applied to limited subset of problems, while new approaches are being adopted from other research fields. This paper debates on two opposite approaches toward multi-objective optimization in architecture: goal- and non-goal oriented methods (see fig. 1) and endeavours to estimate their potential of being implemented in tools for architects.

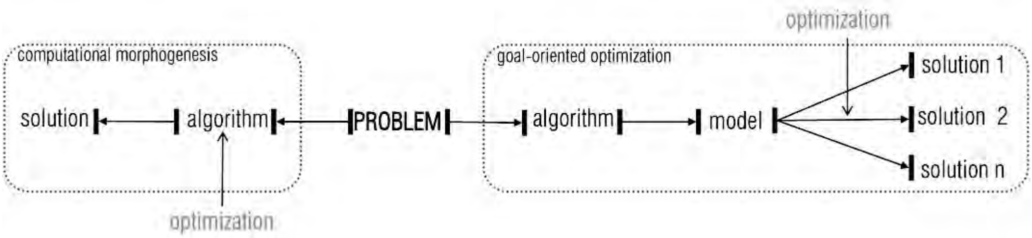

Fig. 1. Potential stages for application of optimization in goal and non-goal oriented approaches.

GOAL-ORIENTED MULTI-OBJECTIVE OPTIMIZATION METHODS

Classification

Multi-criteria optimization in design is a subfield of multiple criteria decision making. In case of complex multi-objective optimization problems, solutions that simultaneously minimizes all objective functions usually does not exist as the criteria are often contradicting. That leads to trade-offs and searching for non-inferior (Pareto optimal) solutions, where one criteria cannot be improved without degrading at least one alternative criteria. Multi-objective techniques accordingly to Hwan and Masud [4] can be divided in the following classes: no preference methods, a priori, a posteriori and interactive methods (see fig. 2).

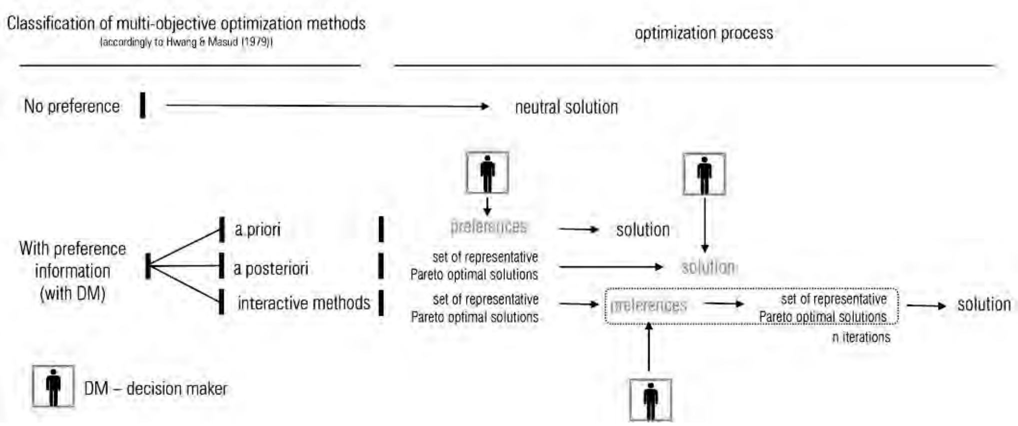

Fig. 2. Classification of multi-objective optimization methods
and the role of human in the optimization processes.

Most design multi-objective techniques can utilize human preferences in optimization processes. In a priori methods, the preference information should be expressed in the mathematical programming problem before the solution search begins. Among a priori methods the most well-known are: utility function method, lexicographic method and goal programming (fig. 3). The posteriori methods in general can be divided into two classes: techniques based on Mathematical programming and Evolutionary Multi-objective Optimization (EMO) Algorithms. In posteriori methods all or subset of the Pareto optimal solutions is produced and the final decision of the most fitting solution depends on the Decision Maker. In interactive methods the Decision Maker expresses his/her preferences at each iteration [5] (fig. 2) that eventually leads to the final solution.

The “no preference methods” seem to be unsuitable for multi-criteria optimization in architectural design, since many factors like aesthetics are incomputable. Moreover, engagement of the “no preference methods” would limit the most crucial characteristic for the designers – creativity. In case of the utility function among a priori methods, Decision Maker can represent his/her preferences as a utility function and then a solution best satisfying these preferences is found. In practice it is very unlikely to construct fitness function that precisely characterizes human preferences. Therefore, among goal-oriented techniques a posteriori and interactive methods, as they facilitate relatively straightforward expression of human preferences, are the most promising for application in multi-criteria architectural design optimization.

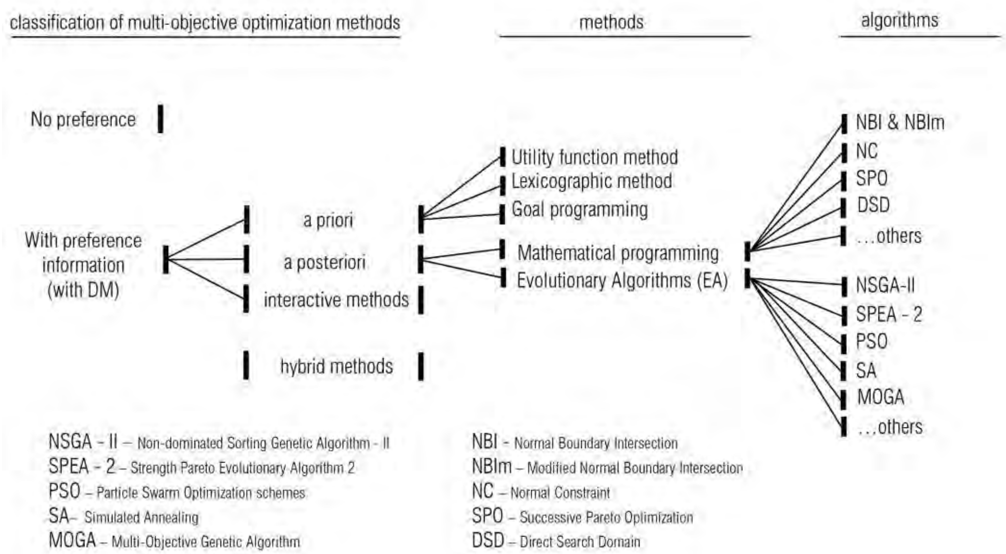

Fig. 3. Classification of goal-oriented multi-objective optimization methods and algorithms.

Algorithms implemented in design software

Existing optimization tools are the proof of concept that a posteriori and interactive methods are very accommodating in solving design problems. This section includes a review of optimization solvers embedded in visual-programming design tools. There are a few 3D-modelling environments with graphical programming languages: Digital Project (2002, Gehry Technologies), GenerativeComponents (2003, Bentley Systems), Grasshopper3D (2008, Rutten for Robert McNeel & Associates), Dynamo (2011, Autodesk), and the latest application Marionette (2015, Nemetschek Vectorworks).

Grasshopper3D for Rhinoceros has gained most popularity in academia and among professionals, leaving the other parametric software applications behind. [6][7] At the moment (March 2015), there are three optimization solvers obtainable in Grasshopper3D: Galapagos (2010, by David Rutten), Goat (2010-2015 by Simon Flory, Heinz Schmiedhofer, Martin Reis) and Octopus (2013, by Robert Vierlinger). Evolutionary Solver based on Genetic Algorithm (GA) and Solver based on Simulated Annealing (SA) were natively implemented in Rutten's Galapagos in Grasshopper3D. Goat interfaces with several algorithms from the NLopt library: Local: linear approximations (COBYLA), Quadratic approximations (BOBYQA), SubplexNelder- Mead variant, (Sbplx) and Global: deterministic (DIRECT), evolutionary (CRS2). Both Galapagos and Goat they are mostly dedicated to solve single-objective problems. They can perform multi-criteria optimization only if all individual objective functions are combined into one composite objective function (Simple Aggregation approach).

Octopus for Grasshopper3D implements two multi-objective evolutionary algorithm: SPEA-2 in its original form and HypE from ETH Zürich. [7] The platform was intended both for searching for a single goal and discovering the best trade-offs between two or more objectives (Pareto Optimal approach). All three solvers for Grasshopper3D rely on interactive evolutionary computation and they meet the requirement of flexibility for architectural design processes.

While three solvers have been already embedded in Grasshopper3D, neither Digital Project nor Marionette has extensions for generic optimization. Among add-ins for GenerativeComponents – there is the prototype Design Evolution – a solver developed in 2011 that uses Genetic Algorithm (GA) (http://communities.bentley.com).

Optimo - a plug-in for Dynamo which performs a Multi-criteria Optimization uses the NSGA – II algorithm (dynamobim.org). Optimo is being developed by Mohammad Rahmani Asl and dr Wei Yan in the BIM-SIM Lab at Texas A&M University. [8] Future versions of Optimo will have support for two more optimization algorithms - SMPSO (Speed constrained Multi-objective PSO) and MOEA/D (Multi-objective Evolutionary Algorithm based on De-composition) (https://github.com/BPOpt/Optimo).

Summarizing, most existing optimization tools for parametric modelling are based on Evolutionary Algorithms. The prevalence of EA in design tools is substantiated by their robustness across variety of design problems and their ability to handle high-dimensionality problems. [9] Currently there are only two solvers: Octopus and Optimo, which are based on multi-objective optimization algorithms and both use EMO algorithms.

COMPUTATIONAL MORPHOGENESIS

There are numerous terms concerning nature-inspired development or computational solutions e.g. Artificial Evolution, Computational Evolution or Digital/Computational morphogenesis. In this paper we refer to morphogenesis (cf.“digital morphogenesis” or “computational morphogenesis”) in architecture, that can be understood as: “group of methods that employ digital media (…) as generative tools for the derivation of form and its transformation often in an aspiration to express contextual processes in built form.” [10] Recent debates on digital morphogenesis in architecture refers to concepts like emergence, self-organization and form-finding. [11]

The idea of interactively evolving designs dates back to Richard Dawkins’ Biomorphs. Both David Rutten [9] and Jeff Clune (endlessforms.com) refer to this work. EndlessForms.com - a project conducted by Jeff Clune at Cornell University that utilizes The Compositional Pattern Producing Networks (CPPNs) mapping techniques. Presented technology is inspired by developmental biology and evolves three-dimensional objects with a generative encoding. Picbreeder.org is a similar experiment that evolves two-dimensional images. [12][13] The Novelty Search technique also proposes evolution instead of optimization toward specific objectives. This new technique instead of rewarding progress towards the objective, rewards novelty in search. [14] It is a powerful method for solving problems in which it is difficult to formulate an effective fitness function. This technique is being explored in research concerning the robotic, art and vehicle industries.

The advocates of biologically inspired forms list the capability to sustain multiple simultaneous functions as one of their main benefits. [15] From this perspective multi-criteria optimization tools might be also developed on the canvas of computational evolution. Although computationally efficient abstraction of biological development is promising for evolving aesthetically pleasant objects. [13] Further investigation is necessary to determine whether it may contribute to the field of architecture. In order to make the approach of evolving design more applicable in architectural problems, the computational evolution may tend to gradual development of form in the pre-described design space. As Adriaenssens says: “Optimization often leads to a large set of feasible shapes, called the design space. In cases where such a design space is explored and we tend to more gradually develop a form, we may also encounter the term computational morphogenesis.“ [16]

Flux - a stand-alone software application could be considered as example of non-goal oriented design approach. As co-founder of Flux, Jen Carlie says, in Flux they design ‘building seeds’ which generate different buildings in various contexts. [17] In the software they managed to automate the import of building and urban codes, therefore on the basis of contextual information the application is also able to generate ‘buildable envelopes on the site’ (https://flux.io/). Such an envelope is an example of pre-described design space and could be also utilized in other generative design strategies.

FUTURE DIRECTIONS AND DISCUSSION

MOO in design tools

EMO algorithms are the only MOO algorithms implemented in multi-criteria design applications so far. The great value of EMO algorithms is the fact that every run of the algorithm produces a set of Pareto optima solutions, while in a posteriori mathematical programming-based methods, the algorithm produces only one Pareto efficient solution per run. Their ability to produce more than one solution is particularly important in solving design problems, therefore EMO algorithms are very promising for further design applications. Future research may aim to increase their computational efficiency, study how to visualize the set of Pareto optimal solutions (Pareto front) in a representative manner and develop methods for effective human interaction with tools.

The hybrid methods, which might be composed from different EMO algorithms or could be a combination of MCDM (multi-criteria decision making) and EMO have not been extensively investigated yet. Their future implementations might leave exiting tools based on goal-oriented techniques behind. One of the promising highly-performing algorithms is Speed-constrained Multi-objective Particle Swarm Optimization (SMPSO) as the single objective version of the algorithm (PSO) managed to outperform the EA – based alternatives. [18]

Role of a human and performance of tools

The interactive nature of Octopus enables users to choose their preferred individuals and change the objectives during the search after every iteration. This is a great value as it makes the process of optimization adaptive and fascinating. Moreover, the possibility to compare solutions is a very handy option in the decision making process. However, freedom in operation on optimization tools requires understanding of algorithms. Although the in-depth understanding is not obligatory to use solvers, the potential users are responsible for defining the phase-space, fitness function and fitness landscape. [19] An “aware” user can provide the correct formulation of the above and can drive solvers across the local optima and push them into exploring “sub-optimal braches and superficially dead-ends”, [9] which eventually lead to better solutions.

It must be underlined, that “the efficiency and success of an optimization is strongly affected by the properties and the formulation of the cost function, and by the selection of an appropriate optimization algorithm” (http://simulationresearch.lbl.gov). Moreover, the improvement in the performance of computational processes may be also achieved by implementing parallel computation.

Reflection

Nevertheless, architecture is not a pure combination of logic and architects should never become form-makers. As Shigeru Ban says about himself and Frei Otto: “Like me, Frei Otto is not a form-making architect, meaning that we always design according to a combination of structural logics, architectural constraints, and programs within the structure.” [20] Architecture is a message, a sign, a creature, which can be truly alive only when designed with soul and the spirit of architecture would never become an issue of optimization.

CONCLUSION

The topic of multi-criteria optimization in architecture forms a new field of investigation. Contributions to this field can be made by further exploration of the Evolutionary Multi-Objective algorithms and the proposition of more efficient algorithms or hybrid methods to be applied in tools. Another research direction lies in the in-depth exploration of non-goal-oriented methods (e.g. Novelty Search, CPPNs) that will indicate the ways for their effective use in architectural design. Although the goal oriented methods seem to be easier to be directly exploited in design tools, the developmental techniques might discover unexpected, well-performing solutions that are highly unlikely to be found by the goal-oriented searches.

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GENETIC ENGINEERING TECHNIQUES IN THE DESIGN PROCESS

Can genetic engineering techniques be applied directly into the design process?

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Mankind attempts to manipulate the evolution of living organisms for centuries, whether by crossbreeding species to eliminate undesirable properties, or directly manipulating in the structure of genes. With the development of information technology and new design techniques for the first time in history it is possible to implement mechanisms driving the evolution of living organisms into design process.

New methods of manufacturing allow for production of complex spatial forms. Direct connection of computers with production machines creates direct bridge between virtual space and the real world. What if we apply genetic engineering techniques to an inanimate object? By crossbreeding individual, functionally different objects with desirable characteristics do we eventually end up with the ultimate object?

New possibilities lead to new questions. What will happen when we apply the principles of the natural selection to inanimate matter? How the rules driving the selection of „the best individual" should be defined? Area of research is unlimited: form finding, optimization, searching for new solutions... It potentially can change completely our way of thinking about design and the role of designer. Inanimate matter treated as a living tissue? What would result from crossbreeding a hammer and a table? A world of new possibilities.

INTRODUCTION

Mankind attempts to manipulate the evolution of living organisms for centuries, whether by crossbreeding species to eliminate undesirable properties, or (since the discovery of the genetic code) directly manipulating in the structure of genes. Goals are different: pursuit of perfection, optimization of selected attributes, and generation of new “design” solutions.

With the development of information technology and new design techniques (generative design, parametric design, genetic algorithms, etc.) for the first time in history it is possible to implement mechanisms driving the evolution of living organisms into design process. New methods of manufacturing e.g. digital fabrication, allow for production of spatial forms of any complexity. Direct connection of computers with production machines creates direct bridge between virtual space and the real world.

What if one will apply genetic engineering techniques to an inanimate object? By crossbreeding individual, functionally different objects with desirable characteristics will the result end eventually up with the ultimate object? What will be the outcome of this process? Optimized object with a different function? Random point cloud?

Evolutionary processes led over millions of years to emergence of increasingly complex systems – from single-celled organisms to us – people. This can lead to incorrect assumption which presumes that evolution tends to create more and more complex systems. Evolution does not have guidelines nor objectives. It is an adaptive process, constantly changing without explicit end.

This kind of emergent design is based on the approach to the spatial forms, as the biological organism which grows, evolves and changes according to the needs of end-users. This spatial form consists of individual components that interact with each other and affect each other creating complex, comprehensive spatial structure. It is a system that can adapt -a change of component parameters mutates the whole structure, without having to build it from scratch.

Evolution is a continuous process that does not assumes any results of its operation. The aim of this article is to investigate the new expression possibilities. Similarly to evolutionary processes, the system being developed by author does not assume any explicit design solutions. The purpose is rather to explore the possibilities to obtain any spatial objects from this extensive evolutionary environment. Will this system generate any object? How those hybridized objects will look like? Will any function or optimization occur?

EXAMPLES OF RELATED WORKS

The section reviews examples of methods that underpin the approach in this paper. A set of presented designs demonstrates the diversity of possible biological design approaches: from simple inspiration with biological processes (Breeding Tables by Clemens Weisshaar and Reed Kram), through trials with emulation of artificial live to the samples of a holistic approaches to the evolution digital emulation. In addition, 3D printing with biological materials shows the possibilities to create truly biological forms evolved in the digital world. Direct link between the virtual world and the world of biological, mutual interweaving of these two worlds

Examples of genetic algorithms and genetic programming in the design process

(1) Kram/Weisshaar: Breeding Tables [1]

Clemens Weisshaar and Reed Kram created a system that produced indefinite number of possible table designs. The designs are generated based on the table parameters relations. The computer is directly connected with the laser cutter which allows to materialize designs directly from virtual world (fig. 1).

Each of the breeding tables is bred according to algorithmic presets and stands equal and individual. There is no longer an ultimate product. The issue of the distinction between the original and its copy becomes irrelevant. Each table is representative of an algorithmic model and simultaneously in her uniqueness, a model for further objects of her species. [1]

(2) Gregory S. Hornby, Jason D. Lohn, Derek S. Linden: Automated Antenna Design with Evolutionary Algorithms [2]

The design was achieved with usage of advanced evolutionary algorithms. Similar to natural selection, each design was evaluated based on the performance capability. Each “individual” was numerically scored and the best one was chosen based on the highest-scoring value (see fig. 2).

The evolutionary algorithms we used were not limited to variations of previously developed antenna shapes but generated and tested thousands of completely new types of designs, many of which have unusual structures that expert antenna designers would not be likely to produce. [2]

(3) FormNation: Chairgenics [3]

FormNation created a collection of chairs which resemble in fact a family of chairs. Recreation of crossbreeding process was used as a creation tool to achieve diversity and surprising results. The brief project description shows endless possibilities of this tool (see fig. 3).

To begin, we had to quantify the desirability of existing chair types. We enumerated a set of traits and assigned a value to each trait on a scale of 1 to 10 (10 being best). Most of these characteristics […] could be objectively assessed. But aesthetics are subjective. So, for our purposes, we relied on a mix of FormNation's own opinions and popular opinion (based on Google and Yahoo rankings). We also decided to limit the number of times we could mate a particular chair model. This was our way of maintaining genetic diversity. [3]

Fig. 1. Kram/Weisshaar, Breeding Tables (by Kram/Weisshaar). [1]

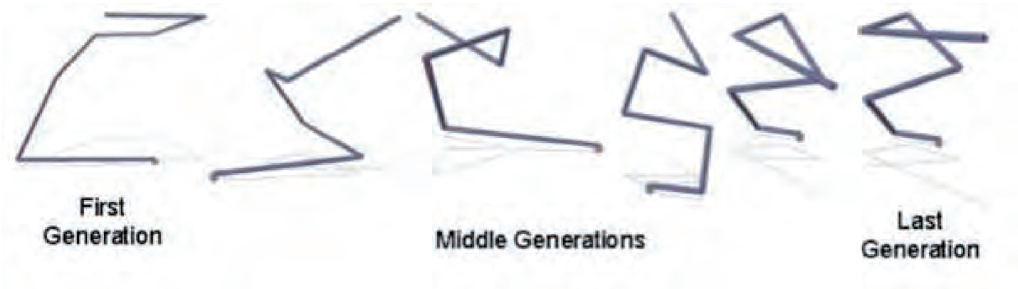

Fig. 2. Automated Antenna Design. Sequence of evolved antennas leading to the final result. (by Gregory S. Hornby, Jason D. Lohn, Derek S. Linden). [2]

Fig. 3. FormNation, Chairgenics (by FormNation). [3]

Examples of Artificial life creations

(1) Karl Sims: Evolved virtual creatures [4][5]

Truly astonishing results can be achieved when using digital computational power one will implement just few basic properties of the physical world into the simulation of natural evolution. Karl Sims study for artificial life creation shows diversity which emerged from just few simple variables (see fig 4).

Research project involving simulated Darwinian evolutions of virtual block creatures. A population of several hundred creatures is created within a supercomputer, and each creature is tested for their ability to perform a given task, such the ability to swim in a simulated water environment. Those that are most successful survive, and their virtual genes containing coded instructions for their growth, are copied, combined, and mutated to make offspring for a *new population. The new creatures are again tested, and some may be improvements on their parents.* [4]

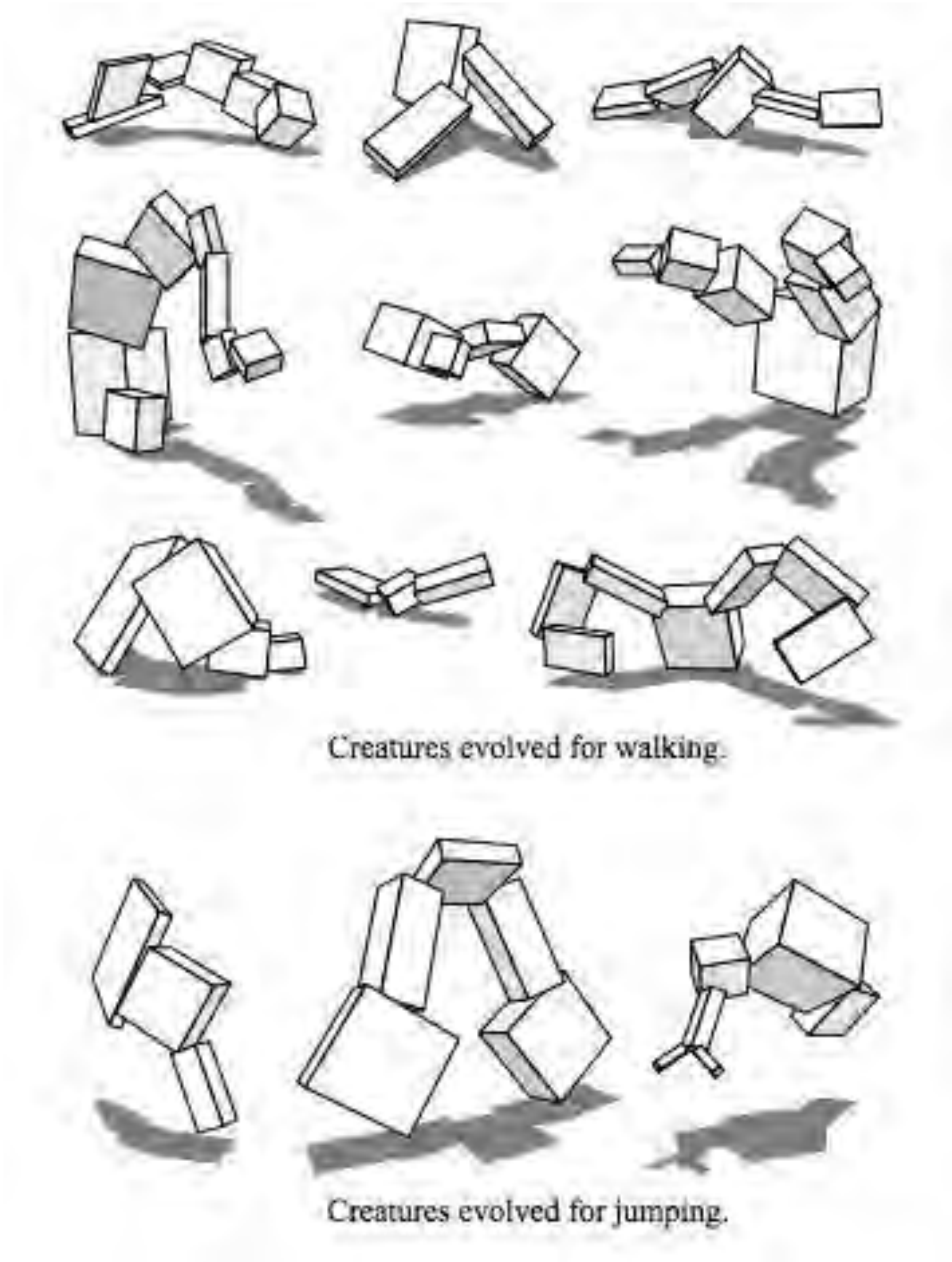

Fig. 4. Karl Sims, Evolved virtual creatures (by Karl Sims). [4]

(2) Hod Lipson, Jordan B. Pollack: Golem Project [6][7]

An example which shows the potential of proposed process is the Golem project - it presupposes creation of an experimental system which is constructed based on the interactions of virtual and psychical world to simulate evolution process of robot-like organisms. Using genetic algorithms, robots are evaluated and optimized based on the virtual properties and data collected from physical environment to achieve the best movement results.

Just as airplanes use the same principles as birds, but have fixed wings, artificial lifeforms may share the same principles, but not the same implementation in chemistry. Every feature of living systems seems wondrous until it is understood: Stored energy, autonomous movement, and even animal communication are no longer miracles, as they are replicated in toys using batteries, motors, and computer chips. [6]

Examples of Computational Creativity and Bio 3d printing

(1) Stephen Thaler: Creativity Machine [8][9]

State of the art invention was created by Stephen Thaler and his company Imagination Engines. He developed a set of neural networks cooperating with each other creating a system capable, with cooperation with human designers, to develop new solutions with creative fashion.

An artificial neural network that has been trained on some body of knowledge and then perturbed in a specially prescribed way tends to activate into concepts and/or strategies (e.g. new ideas) derived from that original body of knowledge. [...] If another computational agent, such as a traditional rule-based algorithm or, even better, another trained neural network is allowed to filter for the very best of these emerging ideas, we arrive at an extremely valuable neural architecture, the patented Creativity Machine. [8]

For example Stephen Thaler used his Creativity Machine to produce the cross-bristle design for the original Oral-B CrossAction Toothbrush.

(2) Eric Klarenbeek: Mycelium Chair [10]

Eric Klarenbeek has created a direct bridge between virtual world and biological systems. Using 3d printing technology he designed a 3D-printed chair using living fungus, which then grows inside the structure to give it strength (fig. 5).

We are the first in the world to 3D-print living mycelium, using this infinite natural source of organisms as living glue for binding organic waste. Once it's full-grown and dried, it turns into a structural, stable and renewable material. Combined with 3D-printing it gives us tremendous design freedom. [10]

Fig. 5. Eric Klarenbeek, Mycelium Chair. 3d printed bio object (by Eric Klarenbeek). [6]

Using technologies of digital fabrication which are available today – 3d printing especially – it is possible to materialize any virtual spatial form. The next step may be a link between the computer and biological organisms by "breeding" them in the virtual space and transfer into the material world with "biological" digital fabrication.

Designs presented above shows different approaches to the same problem. The diversity of achieved results arises from the very nature of the evolution process. Presented computational models show only a small portion of problem complexity. Author's ambition is to create a system that covers complexity of the evolutionary process and evolutionary relations. Evolution is the best design tool invented by the Nature. The system which is being created by the author is aimed to develop a design aid that allows to benefit from the natural design solutions in design process of design artefacts.

AUTHOR’S PROPOSITION AND APPROACH

The proposed iterative process aims to implement the Darwinian selection principles into the design process. Functional objects are brought to form of deterministic characteristics – genome. This is done either by using the "manual" intellectual work, or by creativity machines. The evaluation function is clearly defined value – in the case of genetic algorithms. It can also be determined by a neural network resembling in operation Creativity machines. The next step will be to design an artificial system imitating biological evolutionary processes, the ability to manipulate the genetic code of, "creatures", reproduction, implementation of "disease", etc. mutation.

Author’s proposition aims to use existing computing technology to extend the design possibilities. One can currently observe a number of different use patterns of computing power in the design process. With the growing popularity of digital fabrication tools, 3d printing in particular, multiple designers turned to biology as a major source of inspiration. Above overview shows different approaches to the problem. Author’s concept goes even further. It assumes a complete exploration of the possible evolutionary models as a design tool. It assumes the creation of complete system of "artificial environment" to simulate biological evolution. Evolution is a blind process; therefore proposed utility is intended to assist the design process. It does not aim to replace the designer in the decision-making process. The final selection of the generated forms still belongs to the designer. The designer has an impact on the evaluation function in particular – defines the expected costs, aesthetics, etc.

Entire process begins with defining the basic characteristics of the artefact - the genome. This can be achieved using an "analog" intellectual description or by applying a set of neural networks: one is trained in such a way that it is able to recognize features of a given object, the second one can evaluate those features and distillate the deterministic ones.

Subsequently, on the basis of distilled genome a set of objects is generated. The best individuals from the pool are then selected for breeding process. The evaluation process is made by autonomous system of specially trained neural networks or by fitness function value (fig. 6). This is to eliminate the ones which do not satisfy the search criteria specified by designer (ergonomics, usability, etc.)

Selected individual is then subject to mating process with the individual from another gene pool (e.g. object of different function). At this stage, additional factors which amending the gene pool are introduced - mutations, viruses. In addition, variables of physical environment (e.g. gravity) and environmental pressures (e.g. predation, interspecies competition, etc.) are introduced. Arising individuals are evaluated by a broader set of evaluation function (cost, ergonomics, material optimization, etc.).

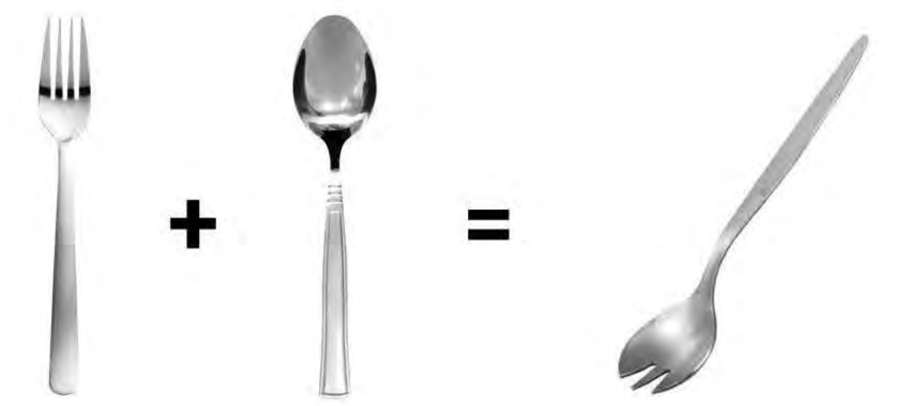

Fig. 6. Crossbreeding objects with different function and form.

The final results are then subsequently evaluated by the designer. The process will most certainly produce odd items that do not have any real world functional value. The designer decision determines the final selection.

If the final results of proposed simulation systems will resemble traditional forms of objects, this will be a proof of correctness of the proposed process. (e.g. hammer form was not designed, was rather "evolved" and evaluated by users in terms of specific functional and ergonomic needs of use)

New possibilities lead to new questions. What will happen when we apply the principles of the natural selection to inanimate matter? How the rules driving the selection of „the best individual” should be defined? What should be the evaluation function? In the future, this technique may be implemented into the biological systems: by encoding algorithm into the cell’s genetic code using the translation of computer programming languages on the genome. The ultimate goal may be the Universal Constructor – robotic stem cell.

This creation method can in the future be implemented to the biological systems. It can be achieved by encoding the results of computer simulations directly into cell's genetic code by the direct translation of computer programming languages on the genome.

A further step could be a creation of nano-machines with implemented algorithm creation. To this, however, had a chance to come, further progress in nanotechnology is necessary The ultimate goal may be "universal constructor" - digital / mechanical / robotic stem cell that can replicate itself using available resources environment.

CONCLUSION

One can imagine genetically programmed objects, which – like a plant – can grow out of the spore and is composed of self-organizing cells. This can be achieved with the advancement in the field of computer technology.

Area of research is unlimited: form finding, optimization, searching for new solutions... It potentially can change completely our way of thinking about design and the role of designer. Inanimate matter treated as a living tissue? What would result from crossbreeding a hammer and a table? Or a table and a lamp? A world of new possibilities.

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MORPHOGENESIS AS A DESIGN ASSISTING TOOL

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The subject of the article is the morphogenesis as a design assisting tool. Author focuses also on morphogenesis of flux structure and presents two methods: Sensitivity Analysis Method and Extended Evolutionary Structure Optimization. Sensitivity Analysis method as a tool for producing logical free curved surfaces closer to those drawn by architect, is explained in examples Arata Isoszaki's projects (Kitagata Community Centre, National Grand Theatre in Beijng) or Toyo Ito's (The Island City Central Park). Another aspects of the article are different evolutionary technics like genetic.

INTRODUCTION

The new architecture, emerging from the evolution of digital technology, is the expression of curved forms with a high degree of complexity. The connecting factor for designers is not only a simple desire to create free forms, but also the use of digital design tools. Modern architectural projects do currently reach for all areas of science, including biology and especially morphogenesis. The origins of interest in this field started with projects of Antonio Gaudi, but the landmark study has been done in the 60ties by Frei Otto and Heinz Isler. Currently a design with the participation of biology is achieved thanks to constant upgrading of the digital workshop tools supporting the design.

Nature has been inspiring builders since time immemorial. In architecture, these inspirations were usually manifested in the creation of forms and supporting systems referring to the elements of the natural world. Also, the interest in logic and plant structure is nothing new to architecture - this is confirmed by a number of contemporary projects, such as the *Santiago Calatrava* station in Lisbon, where foliage of palm trees serves as a leading inspiration. The use of such detailed elements of the biological world would not be possible nowadays, had it not been for a revolution that took place in the first half of the nineteenth century. In today's design solutions and style, architects consciously turn to the forms existing in nature, while spatial solutions are the result of attempts to achieve balance between architectural form and design solution. In 1850 in Chatsworth, the *Regia House* - designed by J. Paxton – was built. Its construction had the design of the system of corrugated ribs, and was inspired by the huge *Victoria amazonica* leaf. This idea was soon repeated in London's Crystal Palace. [1] It is worth noting that, in order to achieve extremely sophisticated forms of these objects, implemented was - typical for that time period – design of glass and cast iron elements. [2]

The new architecture, emerging from the evolution of digital technology, is the expression of curved forms with a high degree of complexity. The connecting factor for designers is not only a simple desire to create free forms, but also the use of digital design tools. The popular CAD system allows for modelling of surfaces and solids, and enables the exchange of data between CAM and CAD environments. It should be noted, however, that these systems are, in a way, an electronic drawing board, and they do not automate the design process. In professional discussion, such traditional design is called *form making*.[17] [3] Its opposite is *form finding* where the form is found by relevant IT processes. Very often, the beauty lies not only in the aesthetics, but also in the conceptual methodology itself. [3] Imagination and talent of the designer are here shifted to the areas of predicting the outcome of certain processes. Digital tools and programs, such as *Rhino Grasshopper*, *Generative Components*, or the *Processing* software, make it possible to generate architectural forms using mechanisms derived from nature.

GENETIC ALGORITHMS

Direct use of systems of processes present in nature would not be possible if it were not for the development of digital tools. Already in the 50's and 60's of the last century, we could witness independently devised studies on the application of evolutionary techniques in solving technical problems, while computing pioneers, such as Alan Turing and John von Neumann, would base their concepts on the fascination with behaviour management of organisms and their learning processes. The concept of a genetic algorithm appears for the first time in the work of John Holland, American psychologist and computer scientist. [4] This term is defined as a description of the criteria subject to the programming procedure mapping natural evolutionary mechanism by assuming strict influence of known laws of genetics. The first step consists of filtering solutions which are most compatible with a set of attributes, and then allowed

[17] The expression form making is of Anglo-Saxon origin, where IT processes are subordinated to actions of the designer. The architect is seen as the creator who specifies the form, while the role of the constructor is limited to carry out all that work as faithfully as possible.

to create another population, with "chromosomes" exchanging relevant portions of information. By presenting alleles bits and sequence reversion, processes of mutation and sequence change the order of information. [5]

It is worth paying closer attention to the definitions provided by specialists in information architecture. Jan Słyk defines genetic algorithm as: *method of heuristic selection, using a mechanism modelled on natural evolution; randomly creates a population of solutions, among which it looks for the results that best meet the criteria, and in next generation uses characteristics from the pool of choice and makes mutations accordingly.* [5]

Krystyna Januszkiewicz, on the other hand, in her book *O projektowaniu architektury w dobie narzędzi cyfrowych (Eng. About architectural design in the era of digital tools)*, describes genetic algorithm, stating that in a defined environment it most often initiates and evaluates the primary population of individuals randomly. Each of them must be attributed to a collection of information constituting its genotype, which gives rise to the creation of the phenotype. The phenotype is a set of characteristics that are evaluated by the function of adaptation which models the adopted environment. [3] The basic genetic algorithm was developed in 1975 by John H. Holland in the FORTRAN software language; later, it has developed thanks to using his works from the 60's and 70's as a foundation. These techniques are referred to as *evolutionary design.*

For a long time, genetic algorithms remained outside the scope of design practice, but Gregory Franck and his team from the Vienna University of Technology *(Department of Computer Aided Planning and Architecture)* decided to use a software solution during solving the systems of housing projections. Being able to use any given number of parameters, automatic control, but also engagement in the simulation process and then manually applying changes, increased the chances of selecting the most optimal solution due to the large number of them obtained in a relatively short time. [6]

An interesting experiment was conducted by Jan Słyk and Anna Guzik, at the Faculty of Architecture of the Warsaw University of Technology, based on the Processing software. The thus obtained programmed transformed a genetically secure population of points from a random system into the solution that best meets the research criteria. Initially, created was the number of twenty groups of points representing irregular systems with regard to their initial state. On the other hand, however, pseudo-random number generator supplied coordinates forming patterns. The results of this experiment were related to the work of Juliusz Żórawski titled *O budowie formy architektonicznej (eng. About structure of architectural form)*, showing that the original population program chose solutions in response to such criteria as the tendency to organize according to straight lines, right angles preferences, tendency to perceive groups of up to five elements, tendency to focus on strong elements.[18] [7] At the same time, in the 1650th generation of solutions, all points would remain in collinear and perpendicular relationships, and there were no points that were separated. [5]

USING GENETIC ALGORITHMS IN THE OPTIMIZATION PROCESS

In the design practice, genetic algorithms are an analytical method of computer techniques based on finite element method (FEM), acting as a very important tool used in the design of architecture that is optimized and sensitive to the environment. Genetic algorithms, in a defined environment, most often initiate and evaluate the primary population of individuals randomly. Each of them must be attributed to a collection of information constituting its genotype, which gives rise to the creation of the phenotype. The phenotype is a set of characteristics that are evaluated by the function of adaptation which models the adopted environment. This can be seen, for example, in the works of the *Emergent Design Group* or *Ocean and North*. A team of researchers from the *Emergent Design Group* at MIT introduced a system called *Genr8*, created for achieving synergy between architecture, artificial intelligence, engineering, and study of materials. The concept involves a combination of an L -System and remaining evolutionary algorithms.

Genetic algorithms used in optimization processes allow taking into account a number of external factors and, thanks to the existing software, make it possible to include in projects, already in the initial stage, factors such as: sunlight, wind strength, or sound management of materials. The author of this article has developed, based on the *Grasshopper* for *Rhinoceros 3D* software, a parametric chain of actions, including points for generations mapped out on the plane (see fig. 1 and 2).

MORPHOGENESIS OF FLUX STRUCTURE

The morphogenesis is defined as: *a process of evolutionary development and growth that causes an organism to development and growth that causes an organism to develop its shape though the interaction of system – intrinsic capacities and external environmental forces.* [8]

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[18] The characteristics of perception, contained in Juliusz Żórawski's *O budowie formy architektonicznej,* based on the theory of gestalypsychology, assumed, inter alia, the existence of tendencies for geometrization, cohesive form, limited number, strong form.

Sensitivity Analysis method: is an optimization method for producing logical free curved surfaces closer to those drawn by architect, the method for generation of free – curved shells It could be said that minimal strain energy in the structure is the mechanically optimal condition. The fundamental equation is given by differentiating the reference variable, strain energy by design parameter.

Sensitivity Analysis method was used during competition of the National Grand Theatre in Beijing by Arata Isozaki and Mutsuro Sasaki in 1998. It is necessary to establish an initial shape that is close to desired shape and then computer will get something closed- evaluating how much a transformation at a node influences to the strain energy's transition in the whole structure.

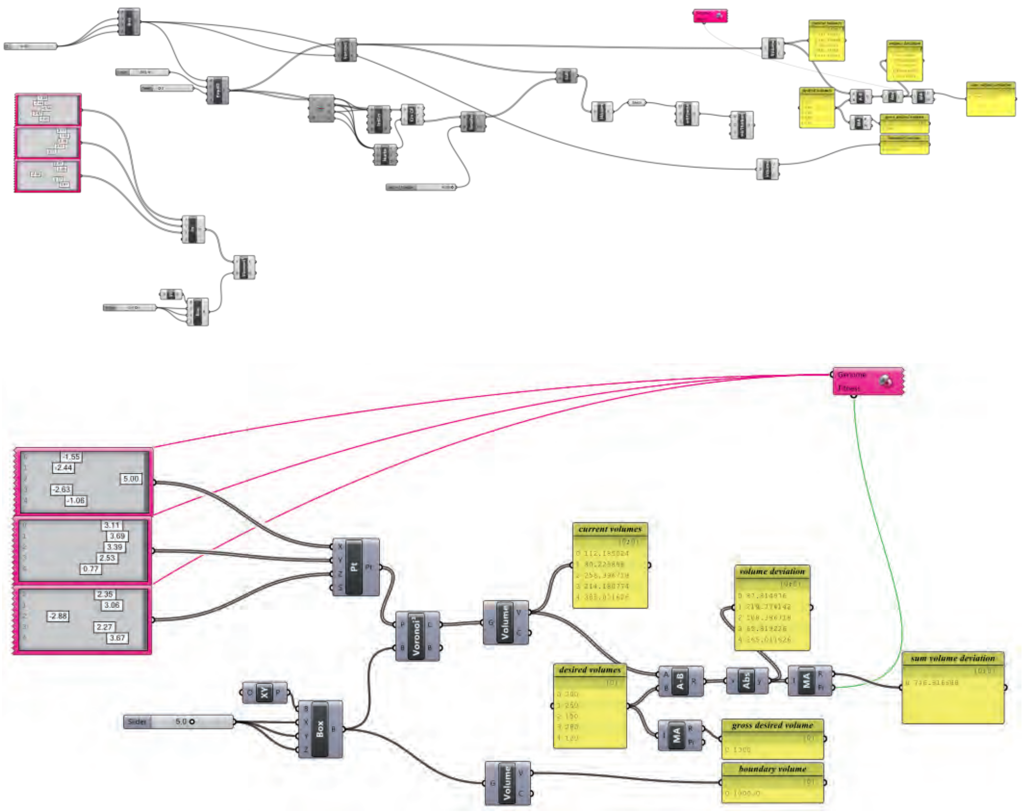

Fig. 1. An example of using genetic algorithm in Grasshopper Software.

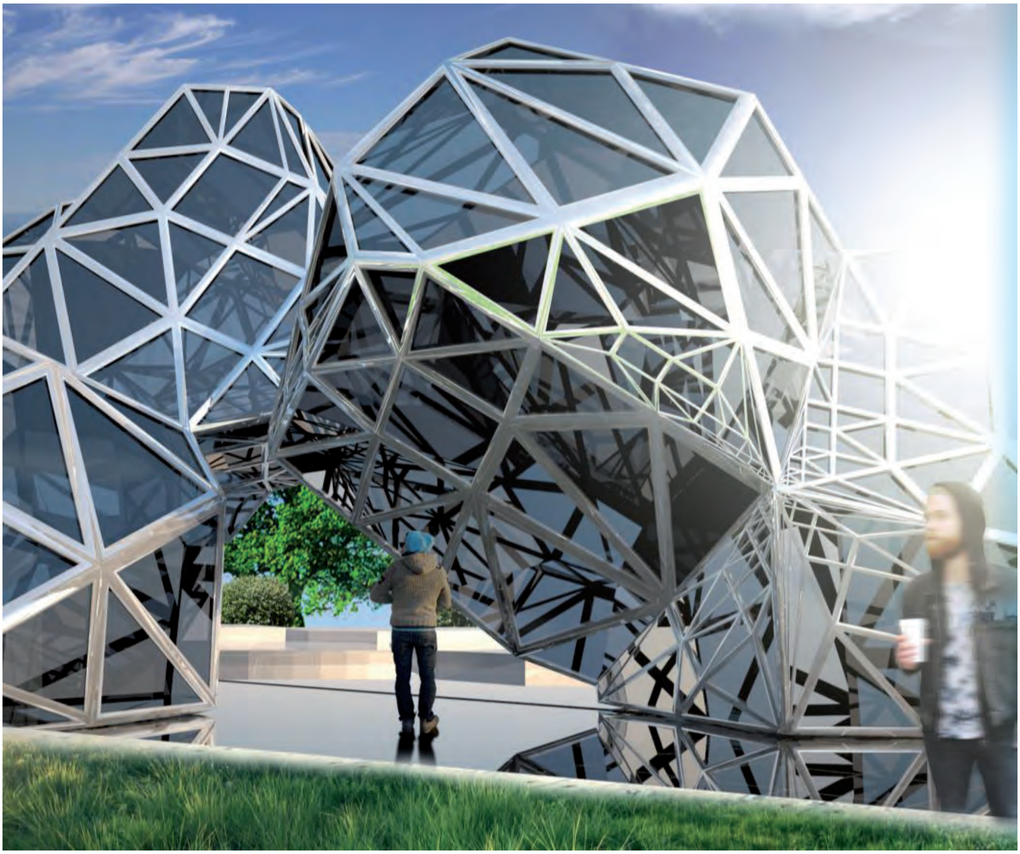

Fig. 2. The result of using genetic algorithm in Grasshopper Software.

The other examples are Kitagata Community Centre, National Grand Theatre in Beijng or Toyo Ito's (The Island City Central Park, The Crematorium in Kakamigaahara, see fig. 3). In this project Toyo Ito also wanted to employ free – curved surface using shape analysis. The Island City Central Park in Gringrin, Fukoka, comprises 3 continuous free – curved reinforces concrete shells with overall length of 190m, a maximum width of 50 m and thickness of 40 cm. A basic study, 190 m long element was treated as symmetrical, a thickness of 40 cm was established using initial shape. The green roof enables the building to merge into the surrounding landscape and allows people to walk on it. It's calculated on the basis of heavy 1.5 t/m^2. [9]

The entire roof was examined by method with the following assumptions:

Material: 40 cm thick concrete,
Dominant load: 1,5 t/m^2.

Fig. 3. The Island City Central Park by Toyo Ito (by WAM).

The NASTRAN software was used for the structural safety of final shape (obtained by the shape analysis was examined through the ordinary structural analysis) (see fig. 4 and 5).

At Fukuoka a combination of ordinary plywood formwork and curved rein was used (see fig. 6).

The subtropical banyan tree has aerial roots braced at several places on the sloping trunk and manages to support itself on this inclination. The stress level is equalized by the principle of uniform stress, which is in implemented by evolving individual shapes – a process guided by the self-organizing capacity.

Extended Evolutionary Structure Optimization (Extended ESO) is a method to generate the most effective structure from its dimension / load condition. ESO as analytical method of computer techniques based on finite element method (FEM), acting as a very important tool used in the design of architecture that is optimized and sensitive to the environment. [9]

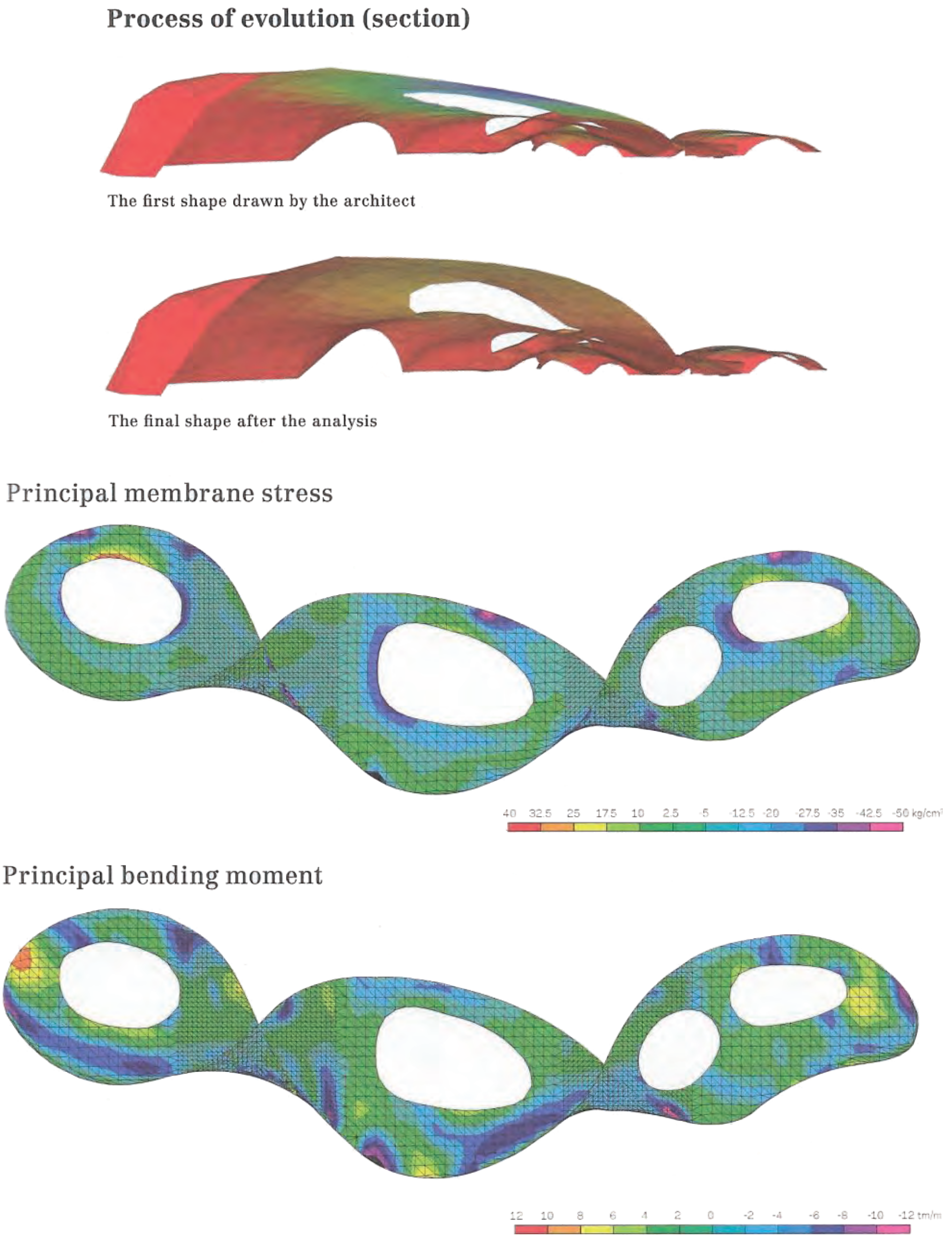

Fig. 4. The result of analysis (by Matsuro Sasaki).

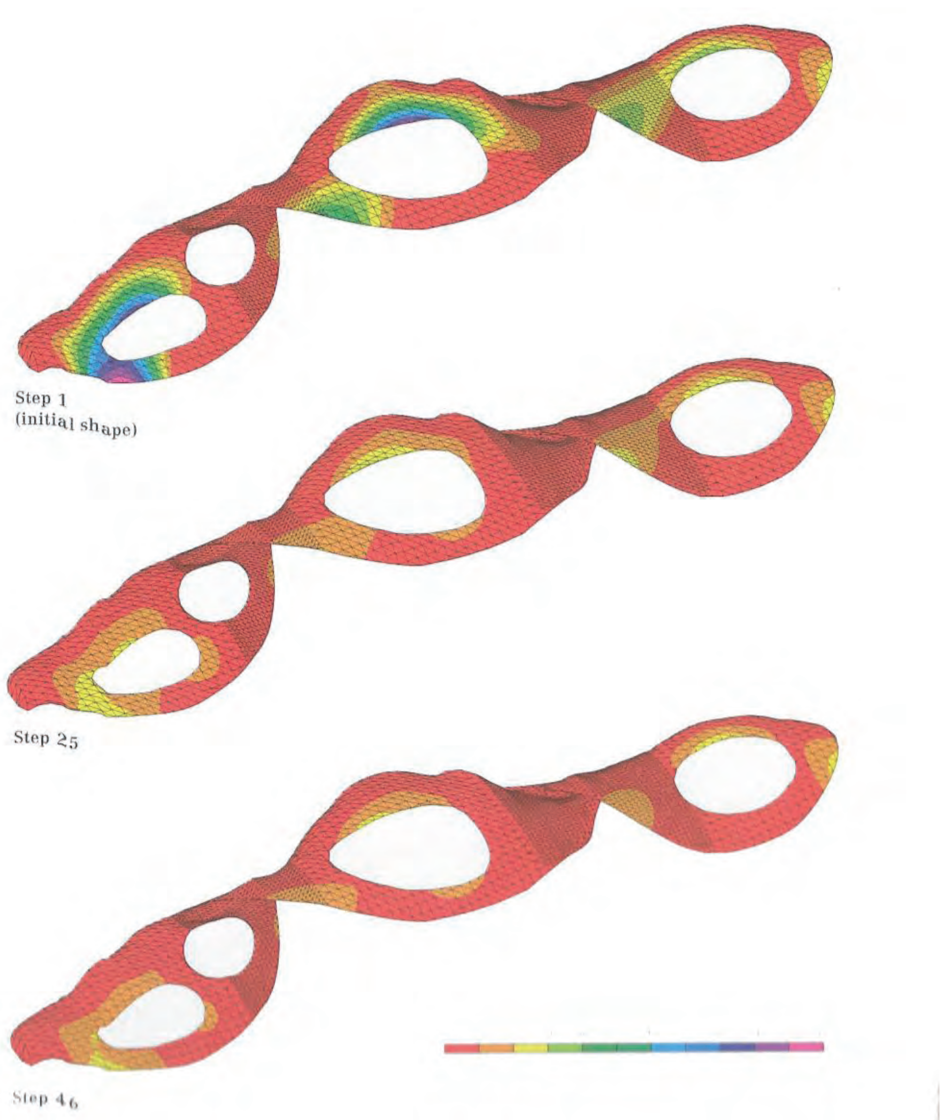

Fig. 5. The result of analysis (by Matsuro Sasaki).

The mechanical optimization of large – span structure will lead to a mechanically optimum form based on the given design parameters. The method was applied in Arata Isozaki's projects like Florence New Station to design of a structural element with a maximum central span of 150 m between support points (fig. 7). The initial state for the roof of design field was a rectangular volume, 36 m wide x 20 m high x 150 m long with support points at each end with a lateral separation of 10 m. [9]

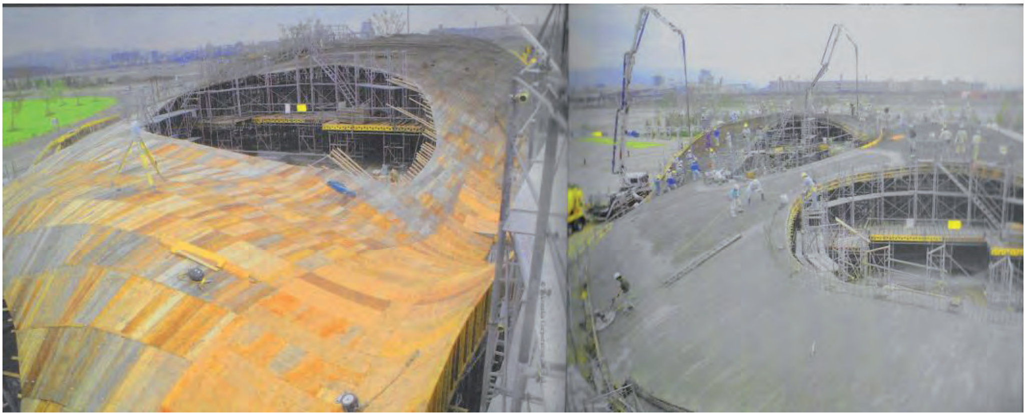

Fig. 6. The Island City Central Park (by WAM).

The method was applied in Arata Isozaki's projects like eg. Florence New Station and Qatar Education City Convention Centre (see fig. 8).

Fig. 7. Florence New Station (by Karmen Franinovic).

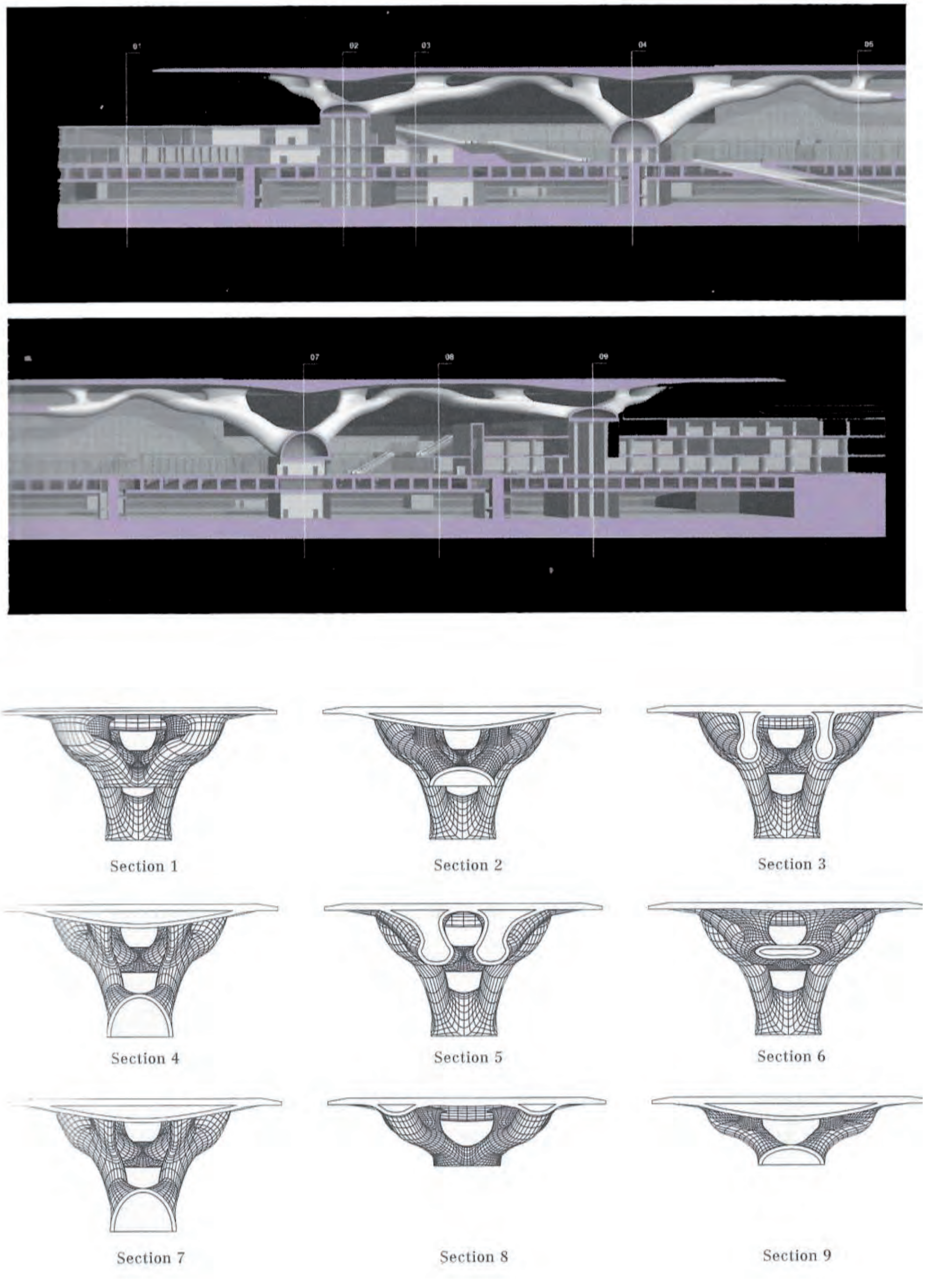

Fig. 8. The result of shape of analysis using ESO method (by Matsuro Sasaki).

SUMMARY

The form- finding method can be helpful in finding the correct way for organizing a building. Natural processes are the perfect study basis for exploring the optimal form, as well as adaptability. Both the development of computer tools and the ability to more accurately map the processes occurring in nature open up new possibilities for designers. Design, including the generative design, by using the morphogenesis processes, also gives us hope for the development of environmental architecture and the popularization of a new approach toward design that not only informs us about changes in the structural logic, but also changes the perception of the environment, focusing on sustainable development and – last but not least - ecology. Perhaps the question about the role of an architect in the world of real buildings may trigger a rather disappointing response nowadays. Regardless of the method of forming architecture, and regardless of the computer tools used, the author always leaves their creative mark. In each of the actions, it is the author who must take care of timeliness, harmony of effects and aesthetic values, which stems directly from the Vitruvian triad: *Firmitas, utilitas, venustas.*

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EVOLUTIONARY HOUSING DESIGN BASED ON CELLULAR MODULES

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This paper investigates the potential application of Evolutionary Algorithms to Architectural Design. The objective is to utilise the emergent qualities of self-organised systems for the search of design solutions. Hence we formulate an experimental setup for biologically inspired design approaches in architecture. In this particular case we work with the task of layout organisation in housing design as it represents a major part of architectural design work. Systems Theory as well as architectural theories such as structuralism support the understanding of buildings as systems of interrelated elements and state that design is concerned with organisation of those elements [1]. Research on analogies between natural phenomena like swarm building behaviour of termites and informal settlements, and architectural design has led to introduction of principles of self-organisation to architecture [2]. The project results in a cellular automaton based generator, defining architectural space-modules, having rules derived from architectural relationships of spaces and having them applied to the system. In solving design tasks the solver is efficient in simple multi-constraint objectives and finds solutions that are sometimes not intrinsically found.

SCIENTIFIC BACKGROUND

Emergence in self-organised systems is used in the search of design solutions by formulating an experimental setup for biologically inspired design approaches in architecture. In this particular case we work with the task of layout organisation in housing design as it represents a major part of architectural design work. Systems Theory as well as architectural theories such as structuralism support the understanding of buildings as systems of interrelated elements and state that design is concerned with organisation of those elements [1]. Research on analogies between natural phenomena like swarm building behaviour of termites and informal settlements, and architectural design has led to introduction of principles of self-organisation. [2]

We want to contribute to the field of algorithmic design which has greatly supported the translation of such principles into design research and practice. Particularly the use of computational methods such as multi-agent-systems, cellular automata and evolutionary algorithms has been discussed as a viable way to deal with excessive amounts of complexity.

To handle high levels of complexity has been identified as one of the main deficits in the capabilities of the single designer's mind [3] and is thus one of the great potential benefits of computational approaches [4]. The problem of complexity is increasing in recent times but on the other hand has always been an inherent phenomenon in architectural design. [3][5][6][7]

The understanding of architecture as complex systems as well as approaches like Structuralism and also the approaches of architectural language, shape grammar and even the theoretical foundations to regard architecture as something computable have built a solid base for the translation of such principles. Ever since P. Eisenman and C. Alexander have laid out the theories – the daily practice (as also education) of architects is still looking like the traditional approach [6] – the individual genius with intuition and human creativity. The paradigm shift is taking place – yet it still has to arrive in the daily practice [6] until we see the inaccessible unpredictable realm of complex computation as reflecting partner for the human designer to extend his mental capacity. So we took the aspect of layout organisation and translated it into a computational setup. Which potentially could be a generic principle for other aspects of the design process as well.

APPROACH & METHODOLOGY

The approach derives principles of cellular automata such as a discrete spatial grids, neighbourhoods and local relations to feed them into evolutionary solvers. The setup makes use of the Grasshopper plugin for Rhinoceros as a common tool for architectural modelling and design. Hence we utilise the accessible solvers of Galapagos and Octopus and test their capabilities for the given tasks. Further it was essential to define a basic linguistic grammar to determine the configurational rules and construct a simple generator-engine to run on them. Different basic setups are tested with different approaches –

such as organising simple patterns, path finding, multi criteria problems etc. The limitations of the solvers and setup are of interest as well as the structure of the genome values and size of search space (fig. 1).

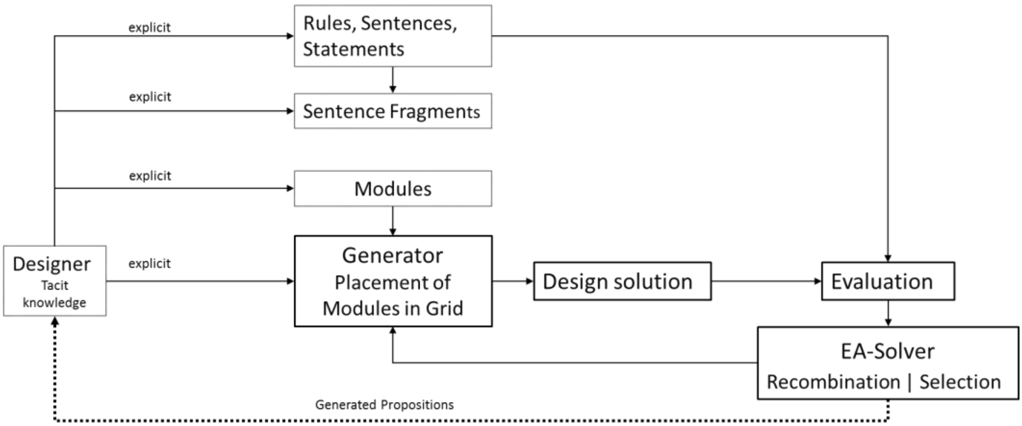


Fig. 1. Process layout.

For this to happen – to bring the design process into computation – a translation has to be done. A certain formalisation is needed due to the quantitative and discrete nature of computation. [8] A resolution of the complex design process into simple parameters is also vital for the use of Evolutionary Algorithms. We based our approach on the theories of a language of architectural form and Structuralism and proceeded in the following assumptions:

(1) Design elements are conceived as cells. This takes into account that nature uses cellular structures for living organisms. This analogy can be equally found in the Structuralist tendency of “Aesthetics of number” [1] which also understands buildings as living organisms. For the organisation of a building design these cells are set in a discrete spatial grid (– hence they are modular.) In terms of algorithmic conceptualisation [6] this might not be necessary for other aspects of the design– yet the effect of emergence can rely on the local interaction of the cells. This is observed in cellular automata whose studies have lead further to the idea of Evolutionary Algorithms. [6] For different design tasks the use of an n-dimensional grid might be needed – for the layout organisation the use of a 3-dimensional grid seems most suitable.

(2) The nature of the design elements is defined by the states of the cells quite like a cellular automaton suggests. Hence the design task is largely expressed as a combinatorial problem and the search space is the sum of all possible

cell state combinations (fig. 2). The size of our search space is the number of all possible combinations of elements, therefore the number of different n-tuples. If the number of different states a single cell can acquire is given by the variable k and the number of cells is given by n, then the size of our search space s is:

$$\mathbf{s = k^n}$$

For example a 3-dimensional grid with the size of 10x10x10 units and 10 different states the size of the search space is s=1E+1000. Suppose we could generate and evaluate every possible solution within 1 millisecond this would take approximately 2,3E+979 times the current age of the Universe.

Further this allows discrete codification of the design into a gene sequence or genome [4]. As Mitchell states [8] “combining is creativity”. In particular, we deal with individual functions, not with whole apartment units. The clustering of apartments still has to emerge. We have to note that besides functions, it is also theoretically possible to translate elements like facades, beams, and the structure into a code.

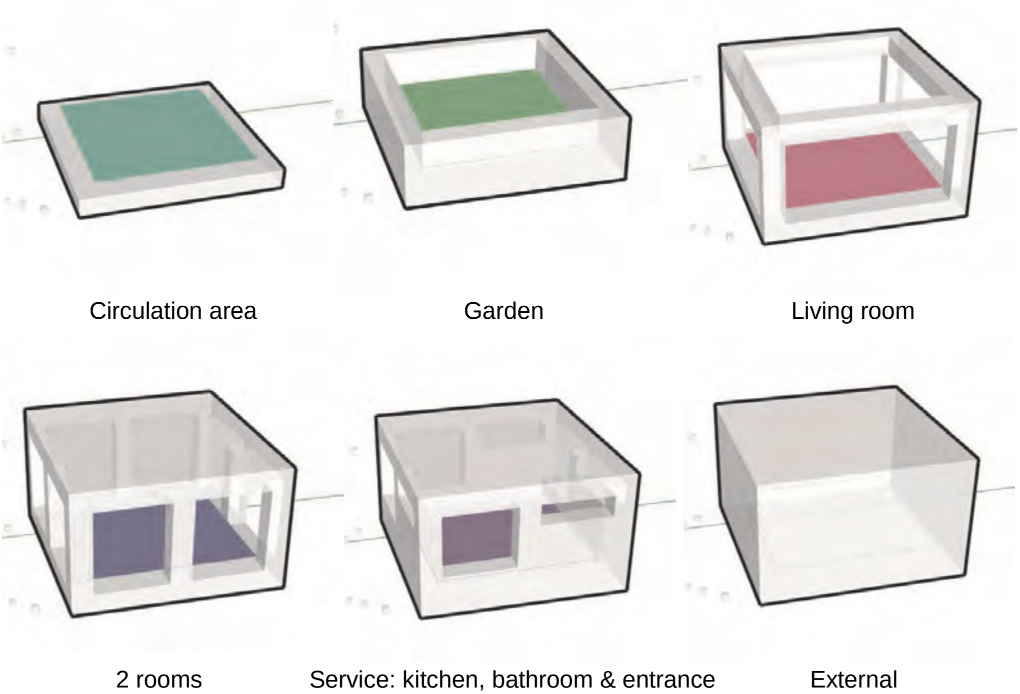


Fig. 2. Possible cell states.

The states are abstractions of the actual layouts – desirably chosen in such a way that later, in actual floor plan generation, a minimum of adjustments is needed to fit the combinations together.

(3) Further the interrelation between those elements has to be defined. Again following the principle of cellular automata we assume neighbourhoods for evaluation – hence the topology is clear. Because in case of layout organisation the direct relation of diagonal modules is less relevant we assumed the Von-Neumann-neighbourhood (fig 3). This simplifies rule generation and computation. Entrances to rooms are rarely placed in the corners – so even diagonal movement is mostly conceived as zig-zag of 90 degree turns parallel to the grid lines. In some cases extended neighbourhoods might be interesting – for example to foster proximity and clustering- that could be of subject for further investigation (fig. 4). Clustering however still should be taken care of to a large extent by the chosen setup. So with this given setup the "Design Universe" [8] is defined.

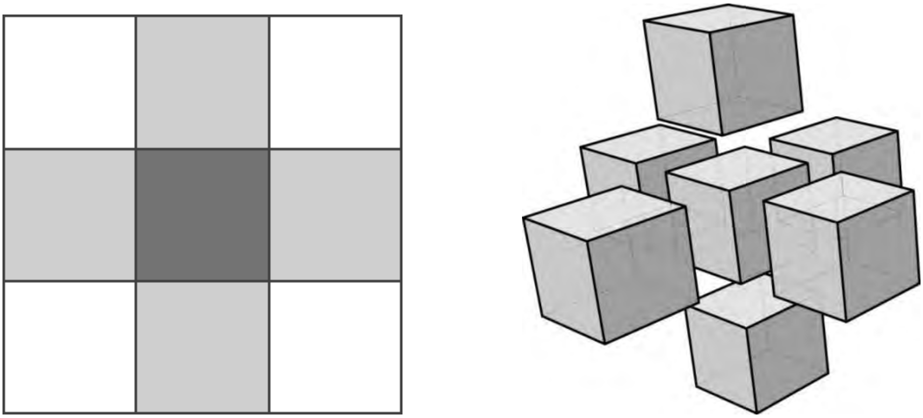


Fig. 3. Von Neumann – Neighbourhood 2D (left) and 3D (right).

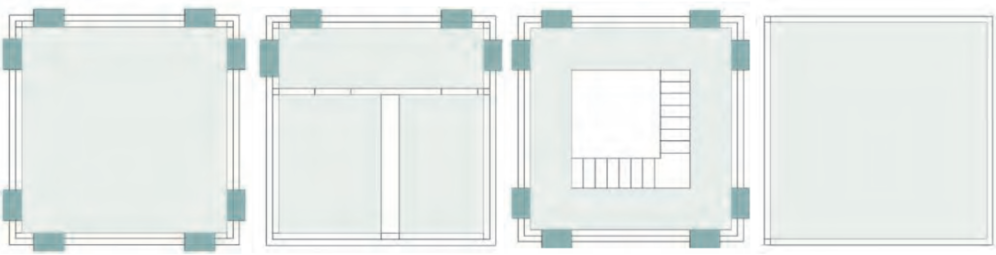


Fig. 4. Potential placement of doors and walls.

(4) To proceed, the exact interrelations themselves have to be formulated. They manifest in the evaluation scheme (and the automaton game rules) of the neighbours. To guarantee a flexibility in the setup of experiments and further investigation, we defined a modular rule generator which combines several modular text fragments into English sentences, similar to building bricks. The nature of these sentences is rather simple and mechanic in order to clearly illustrate the relations and design principles. They can be understood in analogy to design intentions. Here lies one of the most interesting points in the process. If we want to enable the computer to actually design, we need to abstract our design targets in a language that is understandable to human and computer (fig 5).

Fig. 5. Sentence generator translating design intentions/design rules from English language to an algorithmic logic.

Once we defined our targets we have to deal with the hierarchy of those intentions. How do human designers actually organise layouts? Do they work top-down (beginning with grid then placing elements [8]) or do they rather work bottom-up – solving first local problems and then moving on to the next until the whole floor plan is done. Do they have to do it in iterations because any local decision will affect the global result thus rendering it possibly less optimal? Do they constantly switch back and forth between top-down and bottom-up? This can be seen in analogy to the difficulties we have to foresee the moves in a chess game and can be illustrated by the heavy computation their numerical solution requires. In our case we just deal with an incomparably larger search space. Few answers we can possibly contribute from our personal experience as practicing designers. Yet we immediately see the complexity of the task – and the outstanding claim that human individual ingenuity can intuitively handle the problems. Here we see the possible extension of the mental capacity by algorithmic approaches. So the sentences in English language representing design intentions or just organisational rules were translated into the computational logic by simply associating evaluation scales (looking for less and simple rules having maximum performance).

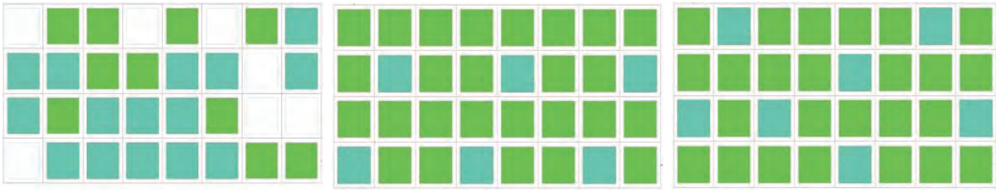
EXPERIMENTS

(1) Simple Pattern

Our first experiment asks whether the given modules are in general able to find solutions by evolving structures, and are therefore comparable with the results of a cellular automata. The setup is 2-dimensional, reducing the Von Neumann neighbourhood to 4 neighbours only. We define 3 possible room states: White, Blue and Green. We set up two rules:

1. Every module Green should have at least one Blue as a neighbours.
2. Every module should be Green. In the first generation already, there is no white module any more.

It cannot be rewarded at all, and therefore is making space for other modules to raise the fitness. After multiple generations, an irregular pattern evolves. This solution is very performant. By trying to find a solution for this set up manually, including systematic strategies as well as tacit strategies, we were not able to compete with the asymmetric solution of the solver. We can consider the outcome of the experiment promising as the solution is unconventional and suitable for the problem at the same time (fig. 6).



A simple pattern, random configuration Fitness Value: 0,60

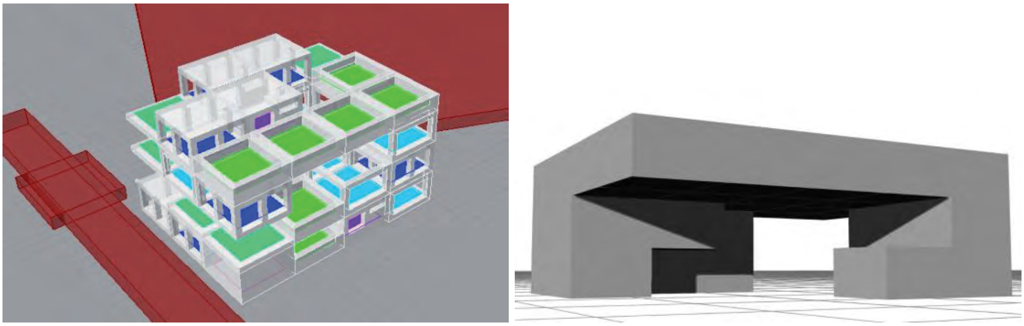
A simple pattern, systematic configuration by human F.V.: 1,40

A simple pattern, solution by Galapagos F.V.: 1,60

Fig. 6. Simple pattern.

(2) Defining Voids via Constraints

The generator can adapt to a certain simple environment by emptying areas from building material. In this case, a box-shaped boundary overlaps with the module structure. This could be a street for example. Modules that are very close to the alien volume are punished unless they change to a certain value that equals free space. After only a few minutes of Galapagos, an interesting structure evolves, avoiding the obstacle (fig. 7).



Shaping the volumes through geometric boundary volumes

A structure making space for alien volume, eg. Street

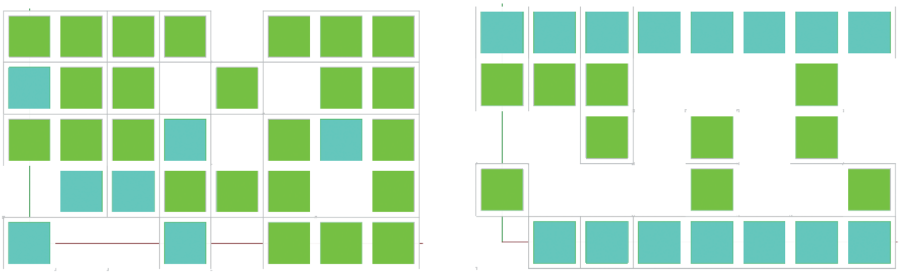
Fig. 7. Defining voids.

(3) Path finding

As our origin intention was to organise infrastructure, making a first attempt to calculate something, will be of a specific value later on. Path finding. An apartment house must be organised in a way that one can reach his or her apartment, measurable as an overall level of accessibility. Usually we can define a path by interlinking points. In order to abstract this, our path is nothing more than a line of free space modules. We set up three rules:

1. Certain areas are supposed to be obstacles and modules in those areas are stimulated to become an obstacle. These make up a frame for our interior space (reward: +5).
2. Every free space with 2 or more free spaces as neighbours is rewarded (reward: +1).
3. Every free space with 3 or more free spaces as neighbours is punished (punishment: -3).

Why would the punishment of rule 3 be larger than the reward of rule 2? If there is a free space A with 3 similar neighbours B, C, D, it receives a punishment, but the other free spaces will probably profit from that constellation as free space A is possibly one of their 2 neighbours. As the system changes the state of module A, this will no longer be punished for rule 3, but also, its neighbours do not receive any more reward according to rule 2. Therefore rule 3 should be at least three times as influential (see fig. 8).



Path finding, random configuration

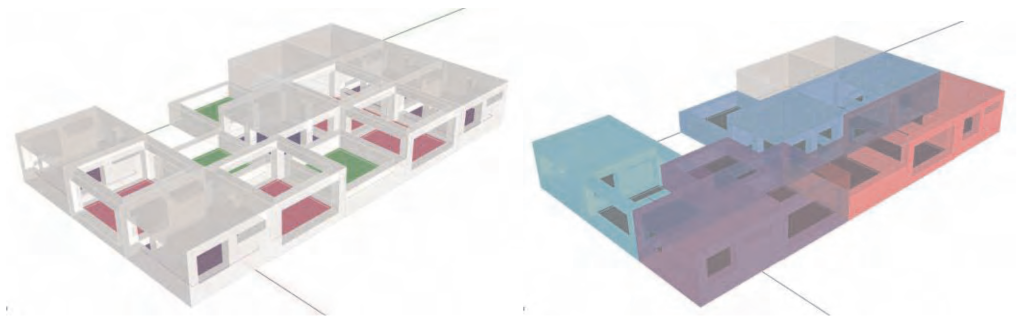
Path finding, solution by Galapagos

Fig. 8. Path finding.

The annealing solver, and the evolutionary solver have different systems to calculate their generations. Comparing different solvers in terms of performance lead to the conclusion that mixing solvers (intentionally) and let them optimise one after another results in the highest measured performance. The generator shows up with a surprising solution that does not really reflect our expectations, but is close to the optimum of the given task. There is one rather long path receiving rewards for every single module. The solution forms one main path that doesn't go through the whole 'building' but ends somewhere in the middle.

(4) Addresses

In the following experiment we will try to address the different modules so that they represent different flats. It is necessary to have a design without serious layout problems. Traffic modules and external building modules have no apartment that they belong to. Image 19 shows an apartment house that was personally designed. The corner in the back is virtually overlapping with another building and therefore not available. During the optimisation process, it is checked whether modules with the same addresses are each other's neighbours or not. To have a better result, it forces this building to split different modules in a way that there is no room addressed the same twice. The result is shown in Image 20. 4 colours represent 4 different addresses. The 5th address is given to the free space and the 2 modules in the back corner (fig. 9).



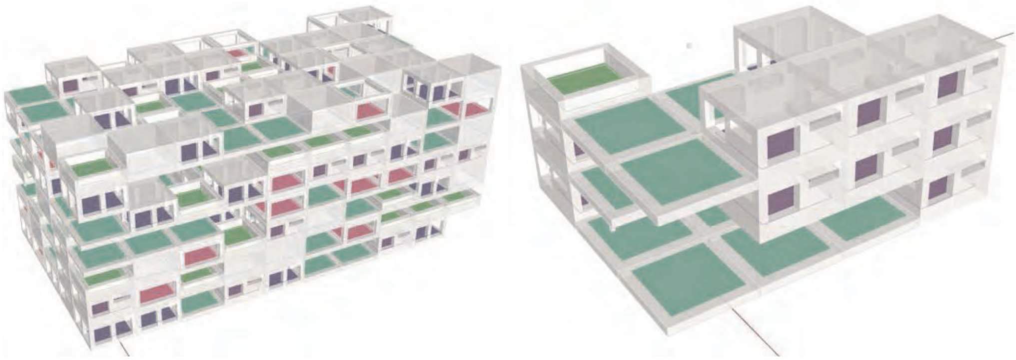
Man-made design of house with one floor

Addressing the modules 4 colours representing 4 apartments

Fig. 9. Addresses.

(5) Comprehensive Setup

Apart from what could be read concerning performance out of the data of previous experiments, it must be said that different types of optimisation were mixed up, and even rules were modified during the process of optimisation. This is not a random parallel between our approach and traditional architectural design work. Almost every rating was changed during the process as due to mathematical circumstances different constellations were measurable positively in ways of the fitness, but relatively unsatisfying. As for the design itself, it applies for the program that the possibilities to reach a fitter result are endless and will therefore hardly be found in a totally structured system. This was actually intended, but not achieved. Over the period of the optimisation, more than 10 rules were added as the building showed up with unpleasing constellations. The actual result is not satisfying neither. There might not be a building according to every rule, without any punishment, to set up, but it is hardly imaginable that there is no better option (fig. 10).



Chaos after 30 mins of sorting by Octopus in default settings

Smaller grid, clearer, yet unsatisfying, 30 mins octopus

Fig. 10. Comprehensive setup.

FINDINGS

In the following lines, we will describe potential problems and solutions that could lead to a better result: The large building of the last experiments has a search space of $7^{60}=5.08021*10^{50}$ solutions. The used computer needs approximately 400ms for one individual. It would take $6.4*10^{42}$ years to evaluate every possible solution. To receive a sensible access to satisfying solutions further performance and a more explicit strategy to navigate through the search space will be vital in the future. Furthermore, there are requirements that are really hard to solve without modules interacting beyond their close neighbours. Logical connections between different endings of the building can be made via swarm intelligence, but it will take more ideas to reach consistent architecture. Modules with single states are not flexible. A contemporary architect, does not design a house with rooms, but with atmospheres, functions, separations and spaces. Those elements do not always have a defined volume, and in fact they overlay. This should somehow be respected in a further project.

Under certain conditions the experiment surprised with a solution even superior to that of a trained architect, in terms of efficiency. Yet in the majority of the cases the algorithm struggled to even complete tasks which were rather trivial and obvious to the human eye. This indicates that humans possess some kind of patterned intuitive solution for which the engine has no quick access. Further it raises the possibility of solving certain problems such as path finding and organising floor plans with the help of such algorithms given sufficient limitation of search space and definition of suitable evaluation criteria. Another possible improvement lies within algorithms that exclude a vast majority of options from the search space. Many rules could be applied before different rules actually collide concerning their design solution and evaluation. This is what a human architect does in his design process too. Some rules are not questionable, may it be laws of physics or basic concept intentions and must therefore not always be weighed against other intentions.

CONCLUSION & OUTLOOK

Firstly we can call it successful to have the cells of a cellular automaton generator defined as architectural space-modules and have rules derived from architectural relationships of composition and have them applied to the system. In solving design tasks the results are not yet satisfactory.

Different improvements in the concept of the software, as well as progression in computational performance allow us to hope for better results in the future. Hence the architect is far from obsolete. The generator acts rather as support for design and decision processes. Yet the role of the architect needs reconsideration. The architect could in fact act as a designer of rules and the generator could become an almost indispensable support in the design process. Therefore the generator can be seen as a tool in designer's hand.

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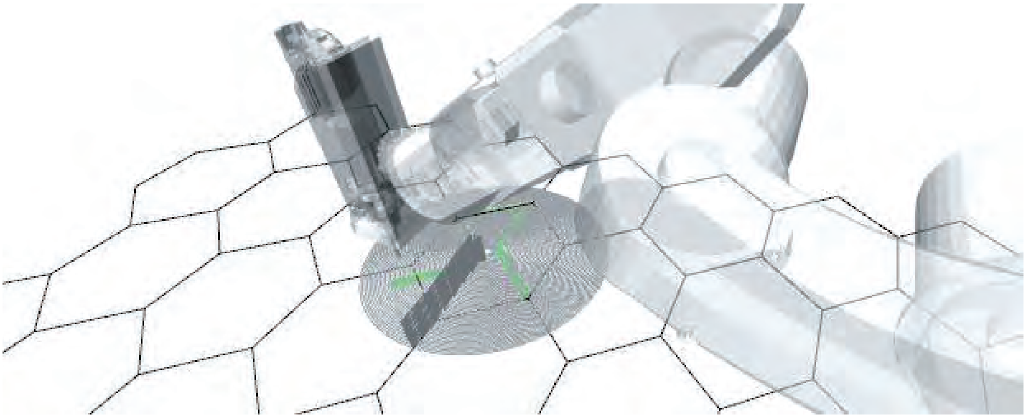
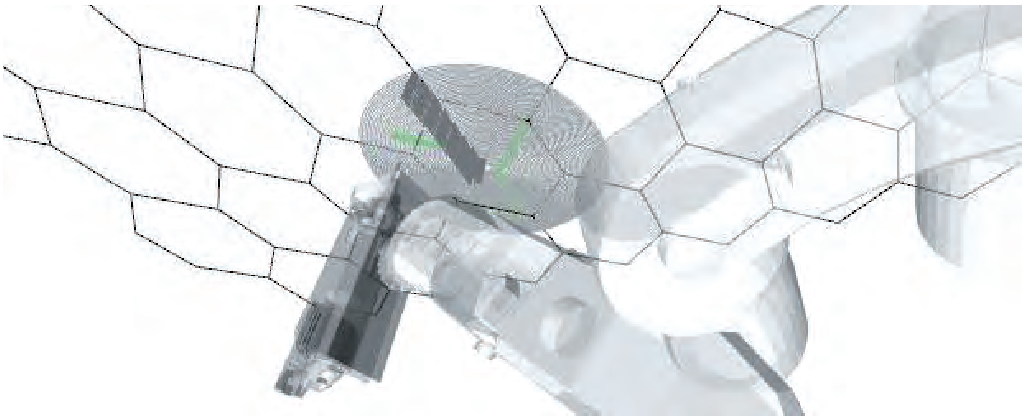


FABRICATION



SQUID: ROPE-GUIDED ROBOT FOR AUTONOMOUS BUILDING PROCESSES

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SQUID is an autonomous robotic system that moves through space with ropes and supported by an overlying construction. This gives the robot better access- and operability for construction sites. This paper describes the current research stage of this robotic system and its possibilities for autonomous building.

Thinking of robots fulfilling a function in a bounded area, we usually view them as ground–connected, manoeuvring around obstacles. Another class of robots are industrial arm robots, with various degrees of freedom, and so-called "delta" robots, often used on production lines for stapling, arranging, and packing. Because of their fixed requirements and rigid arms they cannot be easily placed in architectural surroundings or even in the production of buildings. In last years a new class of 3D printing machines are being developed that can build complex and even large objects. But none of them is suitable for very large constructions, especially on-site and in changing environments.

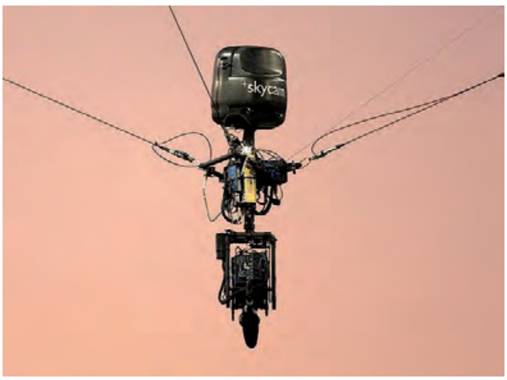
Similar to a giant 3D printer, this rope-guided system can serve different needs in the building process. There are several scenarios of erecting building structures, such as stacking elements over each other as with a brick wall and layering fast-curing materials or two-component adhesive systems. Since this device is suspended by ropes, it offers no pressure on the underlying construction.

Positioning is achieved by changing the lengths of the ropes. This requires a winch system that can be placed either at the cable ends or inside the central moving unit, which simplifies installation. As it's a modular design, additional features, depending on the required function, can be added to SQUID.

RELATED WORK

Rope-suspended machines have been primarily used in film-making and television broadcasting. Their main effect is to access vantage points that are difficult or impossible to reach. The most popular commercial systems are “Spidercam” from CCSytems Inc. and a very similar “Skycam” from Outdoor Channel Holdings, Inc. (see fig. 1).

In recent years there has been considerable research effort at the Alto University in Helsinki, Finland, under the name of “Ceilbot” (see fig. 2). [1] The main idea here is the development of a multifunctional robot acting from the ceiling. The work of Julio Cordon Muñoz is showing the possibilities of a ceiling-mounted fire extinguisher robot operated on a rail-based system. [2] Guillaume Mercier and Massinissa Ait-Gherbi developed the concept of the Ceilbot Robot, [3] a service robot system based on ropes.



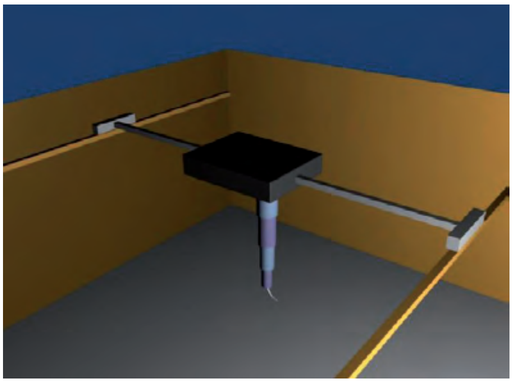


Fig. 1. Hanging Skycam (rope-supported camera) (by skycam.com).
Fig. 2. Ceilbot (fire extinguisher robot) (by Muñoz,Cojon). [2]

New technical possibilities for free-motion in space and stacking architectural modular elements are further developed by Gramazio and Kohler and Raffaello D’Andrea from the ETH Zürich. The idea of “Flight-Assembled Architecture” for building vertical structures uses a swarm of Quadrocopters that autonomously stack boxes (see fig. 3). This system benefits from free upper space for manoeuvres and new self-organised robotic swarm techniques.

There are a few recent examples of robots with a linear top-to-bottom motion system, such as Aaron Fan’s "Pythagoras" and "Kritzler" from Alexander Weber, which works along two axes. In the “Makers & Spectators” exhibition, Niels Völkers, an artist and communication designer, developed a very similar system out of LEGO Mindstorms parts that unifies the hanging robot together with the drive mechanism.

Fig. 3. One Quadrocopter from the project “Flight-Assembled Architecture” is setting a brick module in the process of assembling a tower (by Gramazio, Kohler, D'Andrea, ETH Zürich).

The longest working cable-driven robot is RoboCrane from NIST, with a working age of 16 years. It is based on an inverse Steward Platform, where cables under tension replace the linear actuators. Six cables give the platform six degrees of freedom.

In 2014, Thomas Monroy and Taole Chen developed a “Sky Printer”, which is a hanging device suspended by three ropes that 3D-prints forms out of fast-curing material. This system is interesting for its simple construction and set-up, but is missing precise positioning due to jiggling.

Fraunhofer has been developing an 8-cable-driven system “IPAnema Robot” series, [4] with cables coming from each space corner. The project group, under Dr Andreas Pott, has published numerous articles regarding this system and has made significant contributions for further development.

Parallel to Fraunhofer, a group around Tecnalia Institute is working on CoGiro, [5] an 8-cable-driven robot, with cables located only in four corners. Demonstrations of movement and precision are proven to be very reliable. As this system can also carry weights and leaves the lower workspace area free of cables, it is suitable for construction purposes.

GOALS AND CONTRIBUTIONS

1. Software adaptation of the 8-cable-driven robot to the Robot Operating System (ROS). ROS is applicable for many robotic systems as it incorporates a wide spectrum of libraries and packages for implementing devices. This work will describe one possible way of driving a cable-driven parallel robot in ROS. Simulation in ROS is accomplished using the URDF tree model, which does not support parallel robot simulation.

2. AR_Tags for trajectory tracking as a nonlinear positioning approach. Since no odometry is possible with the current URDF simulation model, this alternative approach gives the possibility to track the actual position of the end-effector and calculate further movement (trajectory) in constant feedback with the current position.

AUTONOMOUS BUILDING ROBOT

Cable-driven hanging robots can be used for various purposes in a defined space. The focus of this work is to develop a 6-DOF moving unit that can be used for building applications. By permitting flexible movement in the upper areas of a construction site, a cable-driven robot can stack building elements in a particular order or 3D-printing large-sized objects. Such an autonomous building system combined with a transfer-solution can be installed in dynamic environments and is the higher goal of further research. In addition, applications stemming from different module combinations will be the subject of upcoming research.

8 CABLES – DESCRIPTION

The main difficulty faced in the development of rope-supported systems is the precise positioning of the hanging device (end-effector). This is mainly because the device hangs on three or four ropes in one level. As the angles between the hanging object and the ropes were not adjustable, a deviation from the null position increased towards the border of workspace. A better and more precise transition of an end-effector can be reached by setting a gimbal-system to the hanging object that points the end-effector to the desired direction; however, even this system cannot avoid shaking and unstable movements (see fig. 4).

By adding an additional level of ropes to the system, a much more stable, rigid and wider workspace range [6] is achieved. Furthermore, this increases the operational degrees of freedom (from 3-DOF to 6-DOF). This development, therefore, is extremely useful for robotic building and stacking purposes where simple rotation operations can be handled without additional motors.

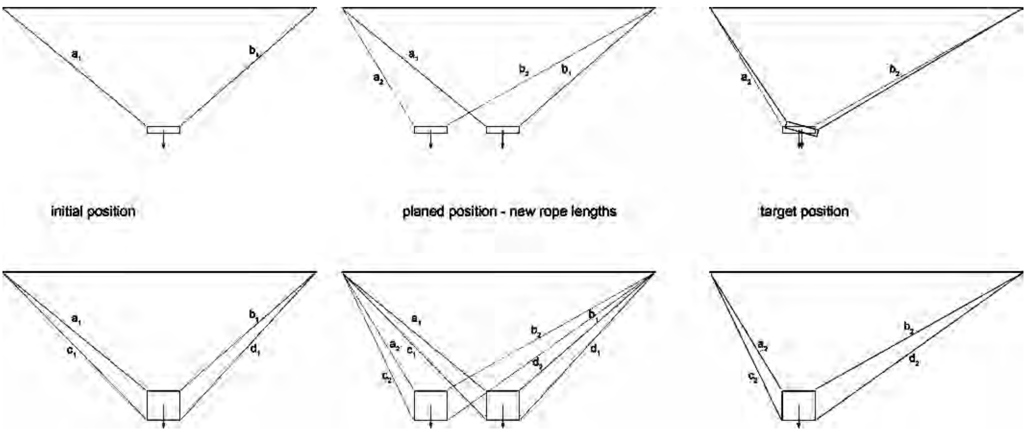


Fig. 4. One- and two-level rope systems and deviations from the target position.

RESEARCH STAGE

With ROS as the controlling system, the robot system can detect visual stimuli to guide its position precisely using the actuators. In addition to linear programming, the ROS continues to activate the actuators after initially “seeing” the situation and adapts the robot state to the desired position. Still, the system is calculating the path and the length of the ropes. This is necessary to define the rotation direction of the motor. With the calculated distance from the actual to the target position the system then calculates the speed of each motor rotation. With the speed data passed to the motor controllers, they move until the end-effector reaches the target position (speed = 0). In the future, this speed factor should be adjustable by a self-optimizing algorithm that responds to oscillation of the hanging robot (see fig. 5).

For a linear programming approach to robot movement, the rope-length calculations must rely on precise and steady winch construction. No change of the winch diameter is allowed as this will lead to non-precise length calculations followed by non-precise movement of the hanging object. This work follows an opposite approach using nonlinear and adaptive control of robot movement; mostly, this avoids complex winch constructions and facilitates operations in dynamic environments. Regardless, visual observation and tracking of the elements in the area of operation are required.

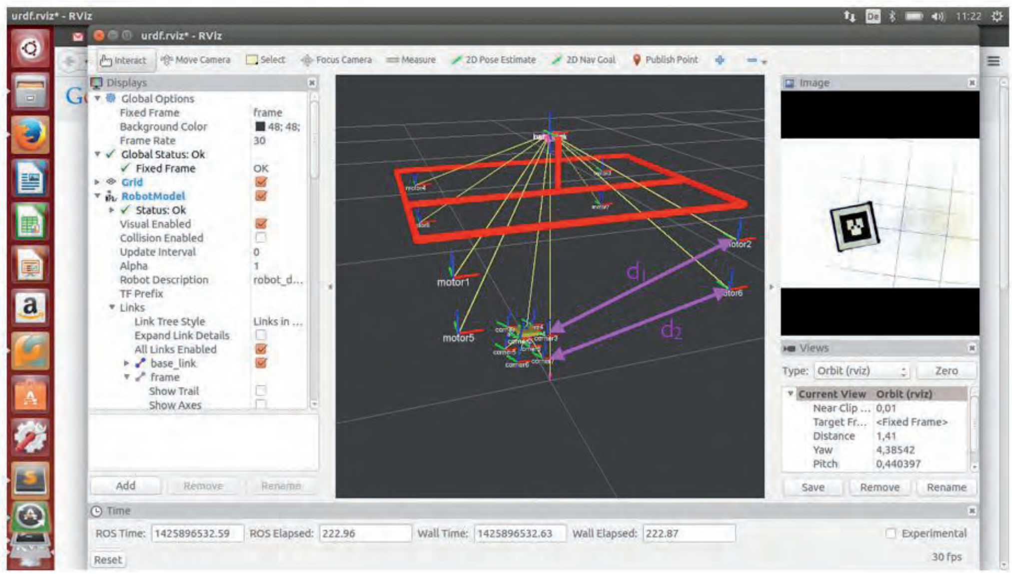


Fig. 5. ROS visualisation in RVIZ of the live setup
and the published rope length (d1, d2) via ros-topic.

The tracking of the actual position of the end-effector (the hanging device) is achieved using live camera images that identify a marker on the top side of its body. Here, we incorporated the ar_track_alvar package, developed by Scott Niekum from Willow Garage, which gives a full 6-DOF pose estimate through calculating the size and distortion of the markers. With its visual detection ability it can then calculate and accurately process information on distance and rotation. Precision depends on the resolution of the processed image; as resolution increases, data size rises as well. This led to the solution that image data is not be processed on one central computer, as initially intended, but the camera gets its own processing unit and passes the calculated information to other components in the system. Using this method, we radically reduce data traffic through the wires.

Although the ROS cannot be used for controlling parallel robotic systems (because virtualisation of the system is not possible due to the closed-loop simulation), here it serves to visualise the present system in real surroundings, control the transformation matrix and to incorporate the motor (motion) commands. With a built-in transformation matrix package called “tf”, we can automatically receive complex transformation information from each point in the observed space. This is especially important for detecting cable crossings during movement and the maximum rotation range. All coded parts are programmed in Python on a Linux machine and, as is typical for ROS development, each programming part independently communicates with other programming parts by publishing and listening to messages. With this system, we can establish a non-interfering thread organisation of different self-programmed services/topics. Yet, some ROS-publishing nodes are very CPU-demanding, especially the tf_static_publisher node, which was replaced by a much simpler Python-programmed publishing TransformBroadcaster node.

As already mentioned, an 8-cable-driven system almost fully utilises the workspace; still, for applications that involve erecting structures by stacking, cables crossing and feeding position have to be taken into account. If feeding is organised from the bottom, then the crossings of the built structure with cables is tiling the action space and reducing the size of possible construction.

If the feeding unit is positioned on the upper level and over the building structure, then the building structures can be placed anywhere under it and it does not have to be separated (fig. 6). Still, the path planning has to consider the synchronous rise of the structure as unequal high parts can lead to cable contacts.

CONCLUSION

Simplifying the winch and calibration system, incorporating a nonlinear moving approach and getting it to work using a widespread robotic software platform (ROS) can move cable-driven robots towards autonomous building robots systems. The control and coordination of the actuators for eight motors becomes complex; however, with the help of ROS-integrated transformation matrix tools and non-intensive pose-tracking packages together with a multithreaded exchange of information between the robot-services, the goal is achievable.

Trajectory tracking and trajectory planning differ from traditional robotic platforms in the way the system is built. The robot adapts to the size of the manipulated space and accurate calibrations of the space constraints are necessary in each new environment.

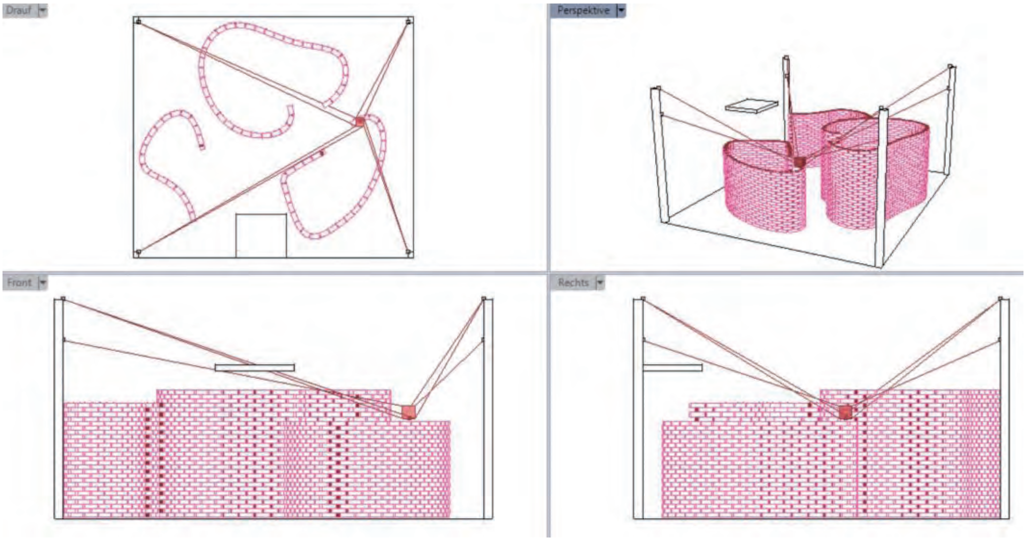


Fig. 6. Upper feeding scenario.

There are several problems that still have to be solved:

(1) Maximising the camera's observing area for trajectory tracking. This means that the camera has to be positioned higher than the actuators; otherwise, it will not be able to cover the whole area.

(2) Tracking of unmarked elements in space, e.g. objects that have to be manipulated. The best option for better "on-ground control" is the blob-detection method, which uses standardised sizes of those elements.

(3) "Camera shadow" problem, where the end-effector is covering the manipulated object. Integration of a camera in the end-effector solves the "shadow" problem and also gives a higher level of precision in motion tracking.

With the option to carry weights at high speed through the workspace and the precise positioning of objects, cable-driven robots are a real alternative to other autonomous building solutions.

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THE 3D PRINTING POSSIBILITIES FOR SOLAR CELLS

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The world is facing a great energy crisis. [1] While in year 2050 the demand for electric power will double, Poland will run out of its main power source – coal. [2][3][4] The law regulations concerning energy usage burdens mostly architects. We no longer have full latitude to implement our ideas into designs due to the energy consumption restrictions.

Solar power is one of the quietest and accessible methods of power production thus we should aim to provide our buildings with such a solution. Unfortunately, the standard silicon solar panels are very hard to adopt as a coherent element of the design. However, the new invention – organic solar cells are not only flexible but also transparent and their colours may be variously modified. What is more, they are very cheap and it is possible to produce them on a 3D printer. [5][6][7] Architects, thus, can easily be both eco-friendly and faithful to their concept.

Besides their obvious advantages, organic solar cells have extremely small efficiencies (no more than around 10% [7][8]) and are very likely to change their colours and properties. They are practically useless a year after the production. However, the kind of energy generator that is sufficient for trees is not enough for humans. The application of organic photovoltaics into building industry is not possible unless both its efficiency and endurance are increased.

ENERGY USAGE RESTRICTIONS

Since the beginning of human civilization until late 19th century the physics of civil engineering was only limited by the construction issues. [9] The 1973 oil crisis was the first event to show the energetic limitations of technological civilization which included the energetic barriers of building industry. It was around that time when a concept of the passive house was first invented and a thermal isolation of the house walls became a norm. The various kinds of layered walls evolved. Due to the strict environmental protection requirements architects recently deal mostly with problems concerning the minimization of disadvantageous houses' influence on the natural habitat. It is the first time in human history when we have approached the ecological barrier.[10] The certain stage of energy limitations was achieved in my country when on January 1st 2009 the amendment to the Polish building code concerning the directive on the energy performance of buildings came into force.

The above changes in building code are not temporary. During the last century mankind became completely dependent on the electric power. [11] Electricity provides us with medical and house equipment, information, communication, free time activates and light. So far the growth in population was always followed by the augmentation of energy consumption, for example between 1970 and 1990 the global population increased by 43% and the energy consumption grew by 59%. [3][11] However, the prognosis of energy demand may not only be based on demographic forecasts. It varies in different countries according to the stages of their economic development and current energy consumption. In 1999 the annual expenditure of energy per capita in USA and Canada was 317-319 GJ while only 7 GJ in Nigeria and 3 GJ in Bangladesh.[4] Whereas in the USA the upward trend remains at the constant speed, it is anticipated that in 9 other most populated countries of the world (India, China, Pakistan, Indonesia, Nigeria, Brazil, Bangladesh, Ethiopia and Republic of Congo [3]) the energy consumption will have reached the value of 85 GJ per capita by 2050. [11] Provided that this predictions are correct, the total energy consumption in 2050 will be about 395% its value in 1998. [1][3][11] According to the International Atomic Energy Agency the energy requirement per capita in 2050 will double in almost every region of the world. [4][12]

THE ROLE OF ARCHITECTURE IN CLIMATE CHANGE POLICIES

One may ask why should we burden architecture with all of the ecological regulations while both China and the USA were not restricted by the Kyoto Protocol? [13] The answer to this question is identical with the one to "why does average citizen need to pay taxes?" It is much easier to make ordinary people bear costs of climate reparation than to come into conflict with the powerful global companies. The other important question is whether it is such a torment for an architect to construct ecological solutions? After all, the desire to catch up with the genius of the nature has been the humans' dream since time immemorial. Is it not an accident that the shapes of the most admired pieces of architecture resemble shells (ex. Guggenheim Museum in New York by Frank Lloyd Wright) and parts of a body (ex. Bubble House in Graz, Austria, by Antti

Lovag) or they simple have façades imitating a meadow (ex. Musee du quai Branly in Paris by Jean Nouvel). The separation of industrial and residential parts of a city was one of the first postulates of International Congresses of Modern Architecture. [14] Contemporary houses equipped with all the media are themselves factories of contamination. The absolute separation is no longer possible. We must enter the next stage of architecture's development in which we no longer move the pollution aside but clean it instantly.

SOLAR PANELS AS FUTURE

The easiest way to deal with pollution is not to produce it. This assumption calls the attention to renewable energy resources. Among the most accessible ones are wind, sun and water. Regarding the need of the river in case of hydroelectricity and giant scale of windmills the only reasonable solution for a building scale are solar panels.

The first silicon solar panels were created in 1954 and have been perfected ever since. The goal is to create a material that is the cheapest and most efficient at the same time. [15] Currently the solar panel market is dominated by the 2nd generation modules while scientists are improving 3rd generation ones. Every next generation is less effective, more ephemeral and cheaper than the previous one. The first and second generation solar panels are made out of silicon – crystalline and amorphous one correspondingly. They are stiff, dark coloured and expensive to produce. [16][17]

The 3rd generation is a whole family of various inventions among which are modules based on quantum dots, nanotubes or hot carriers along with organic and multi-junction ones. [17] The solar modules based on organic cells can be easily adjusted to the colouring and cubature of a building while being very cheap. No wonder that they have caught architects' special attention. [6][7][8] The example of the organic solar cell is presented in figure 1. Thanks to this innovation solar panels can become a fully integrated part of the building for the first time in history.

THE MECHANISM OF ORGANIC SOLAR CELLS

As architects are often mislead by companies eager to have their products sold, they must acquire a minimum knowledge of almost every modern inventions. Figure 2 depicts the basic mechanism of organic solar cells. The active layer is comprised of donor and acceptor material. [16] The incident photon generates a singlet exciton – a bound state of an electron and an electron hole acting on each other by the electrostatic Coulomb force. [18] Created excitons move towards the acceptor and separate into holes and electrons at the interface. The electrons and holes later diffuse across the acceptor and the donor respectively until they reach electrodes. [16] That is how an electric current is generated.

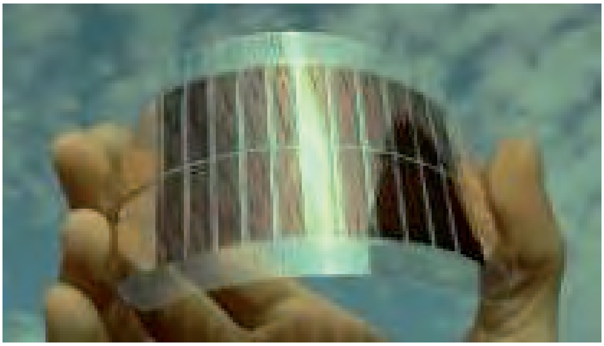

Fig. 1. The flexible organic solar cell (by: exposolar.org).

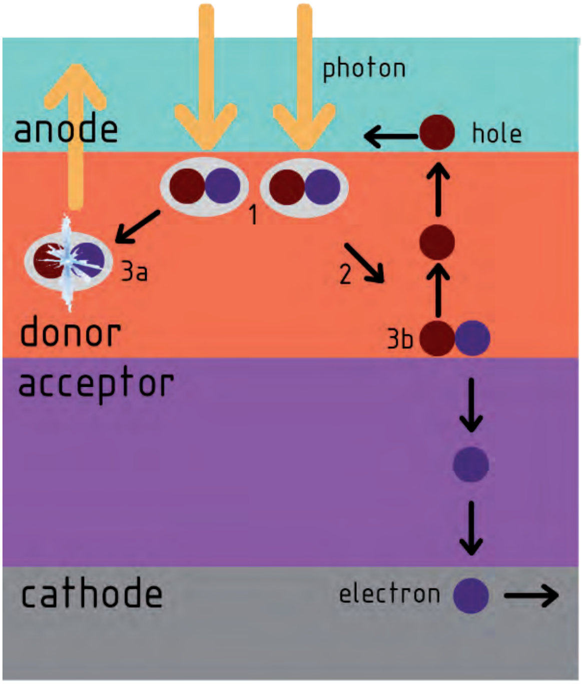

Fig. 2. The basic mechanism of an organic solar cell: 1. Exciton generation, 2. Diffusion, 3a. Recombination, 3b Charge separation.

PRODUCTION

One of the main advantages of organic photovoltaics is that it can be simply printed 3d. Due to this aspect they are incomparably cheaper than silicon modules. [5][6][7] Dust particles can lead to short circuits in the nanometer-thin layers so the production process requires very clean working conditions. [24] The 3d printer single nozzles used for plastic are suitable. [6] Layers are printed on each other with a certain time gaps in order to allow materials to dry (see fig. 3).

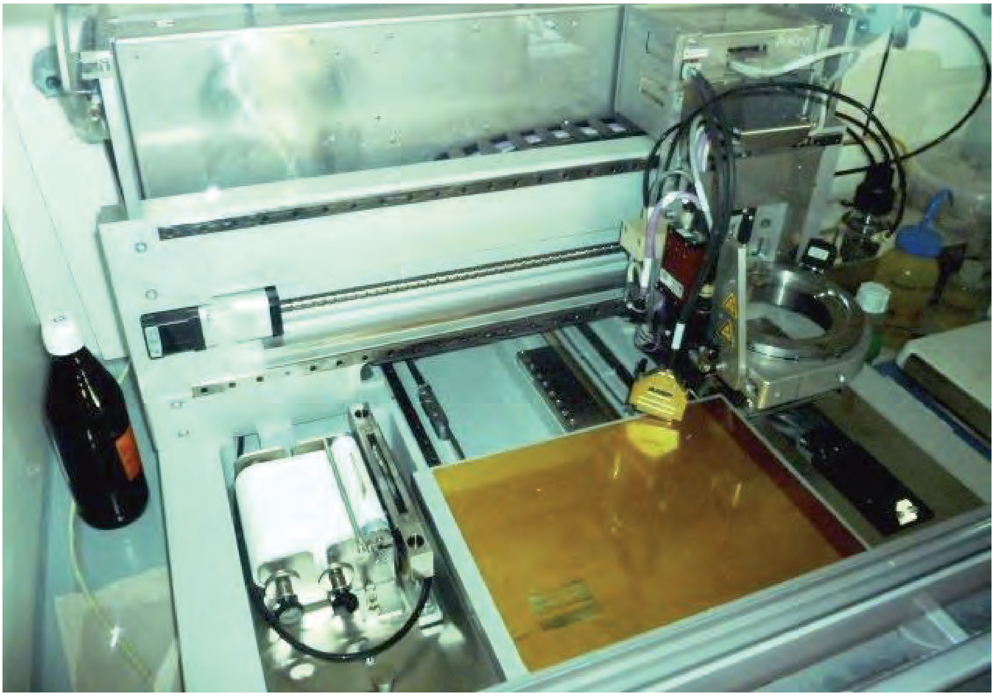

Fig. 3. The organic solar module printed 3d in the Wrocław Research Centre EiT+.

The fundamental structure of organic solar cells is depicted in figure 4. The active layer of organic solar cells is made of completely organic substances, which tend to decay after a relatively short period of time. Among these materials are small organic molecules, conjugated polymers, or combinations of molecules and polymers - typically phthalocyanines, fullerene (C60), oliothiophenes, or polymers. [16]

Organic solar modules have a bilayer or a bulk-heterojunction structure. Since the charge separation only occurs at the interface and the exciton sometimes does not have enough energy to reach that region, it may recombine back to a photon before it has a chance to produce electric current. Unlike in bilayer structured cells, in bulk-heterojunction ones the donor and the acceptor are mixed and only one layer of an active material need to be printed. [7][17] Such a solution is very profitable because the area of the active interface is significantly increased while the distance the exciton has to travel is greatly reduced. [7][16]

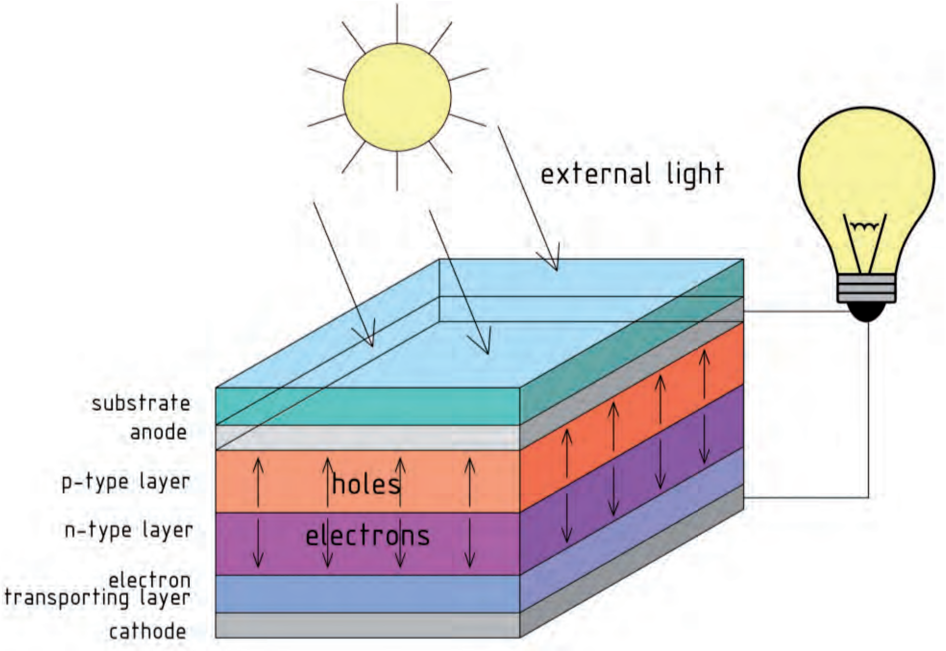

Fig. 4. The fundamental structure of organic solar cells.

The electron transporting layer is usually the indium tin oxide glass while the substrate is a transparent plastic. [16] In order to increase efficiency, an active layer may consist of more than one polymer. [15][17] The presents of anode and cathode is essential for the transportation of the created electric current. Since photons have to act on active polymers, the substrate and the top electrode need to be transparent. [7][16]

3d printing also allows technologies used for increasing the photo effect's efficiency. For example, if the substrate layer is grooved, light has more opportunities to be refracted (see fig. 5). [7] 3d printers are excellent for arduous formation of the furrows. What is more, many beams of light remain unused as they are reflected from the outer layer. The reduction of this effect can be achieved by the introduction of an anti-reflective layer, which can also be printed 3d. [5]

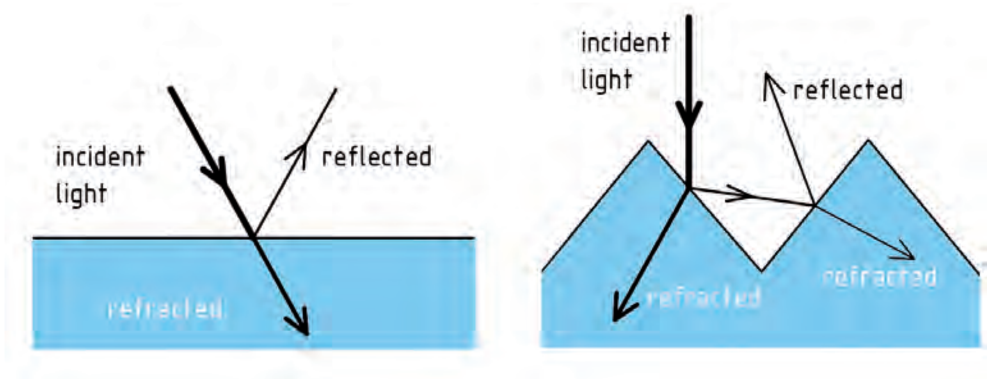

Fig. 5. The scheme of the solar cell's increase in efficiency thanks to the decrease in number of reflected sun rays. This phenomena can be obtained by the modification of the surface geometry.

Unfortunately, not all kinds of organic solar cells can be printed 3d so easily. The biggest efficiencies are obtained by the tandem solar cells – their efficiency can theoretically reach even 68,2%. [19] Materials for such modules are produced by adding atoms of different elements to the semiconductor of the active layer. This can only be achieved by methods which require high temperatures and vacuum. [19] In such solar cells, the 3d printers can only be used for the formation of electrodes and the substrate.

APPLICATIONS

Organic solar cells as a part of facade finishing are becoming gradually more common. Although the examples of PV panels' application are rather scarce, they meet wide public approval. For example, the Cardenal Herrera University created the SML Solar House which was equipped with a PV façade (see fig. 6). It could be visited in the Spanish Pavilion at Venice Biennial 2010. Solar panels entirely satisfied its energetic demand. The house had previously won the first prize for Industrialization and Market Feasibility in the competition organized by the American Energy Department and the Spanish Housing Ministry. It was also remarked by the judges in the category Architecture, Engineering and Innovation and was most voted for by 190.000 visitors who attended the competition. [20]

Another widely recognized case of organic solar panel application can be visited in San Francisco, USA. The Lundberg Design's MTA transit shelter, created in 2009, has the organic solar modules embedded in its wave-shaped red roof (see fig. 7). They provide energy for its LED lights and Wi-Fi routers. [21]

Such a solution is possible as Konarka Technology's Power Plastic, used in the shelter's roof, is available as 70 × 34 cm thin, flexible solar-gathering product. It is able to operate between -20ºC and +65ºC and provides 3.9 W or 7.9 V at 1 Sun (full outdoor sunlight). An increase in photon collection is achieved without the need for angle mounts or expensive tracking system by the wave-shaped canopy gathering sunlight from all angles throughout the day. The city plans to solarize another 300 bus stops. It will generate extra 43,000 kilowatt-hours a year. [8]

Fig. 6. The Spanish Pavilon at Venice Biennale 2010 equipped with a PV façade (by onyxgreenbuilding.wordpress.com). [20]

ADVANTAGES AND DISADVANTAGES OF ORGANIC SOLAR CELLS

Organic solar panels manufacturers tend only to point out the virtues of their products – it seems there are no downfalls. Flexibility, lightness, low price, transparency and the possibility of colour choice are indeed their undisputed advantages. Thanks to them houses - an artificial human violence on an earthly habitat - can finally become cohesive part of self-sufficient natural environment. Why do not we see the organic solar modules all around then?

Fig. 7. San Francisco Bus Transit empowered by organic solar cells
(by Ryan Hughes, Lundberg Design). [21]

Many companies claim that, unlike silicon solar cells, organic ones may reach higher efficiencies during cloudy days. [22] It is true that the dependence of the amount of sunlight on electric response of the organic panels is not linear (unlike in crystalline solar modules) and they may in fact produce more electric current at the dimmed light conditions. However, at the moment the effectiveness of the organic cells is no more than about 10% [7][8] while the one of silicon cells reaches around 15%. [15] To sum up, organic panels may produce relatively more electric current on cloudy days but they still are not able to equalize the 1st and 2nd generation panels.

The matter of cells' transparency and the colour choice is also debatable. The ageing effect on organic solar cells produced by the Wroclaw Research Centre EiT+ is presented in Figure 8. After a year organic modules tend to change colour and limpidity. As their dielectric structure is not fully uncovered yet, and architect can never be sure what colour will the façade have after just a few months. The alteration in appearance is followed by the rapid downfall of panels' efficiency. After a year they are practically useless and need to be replaced.

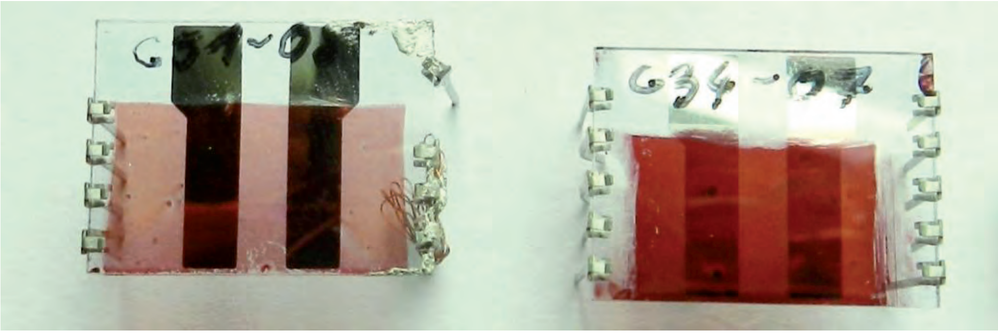

Fig. 9. The ageing effect on organic solar cells produced by the Wroclaw Research Centre EiT+ - the comparison of the freshly produced solar cell (left) and the 1-year-old one (right).

Their vivid colouring can also be both a virtue and a drawback. Human eye can perceive colours because a certain light wavelengths are reflected from the material's surface. [24] The perception of black colour means that all of the visible light frequencies were absorbed thus the maximum amount of photons was absorbed. Black solar panels are therefore most effective. [6] Another property that carries both shortcomings and merits is module's flexibility. Although it enables users to place panels wherever they want, they must keep in mind that sunrays can only reach certain sides of a building. What is more, when panels are artistically fixed on a façade, the installation of tracking systems is no longer available.

CONCLUSIONS

Oddly enough, according to the PV News, the growth in production of photovoltaic panels between years 2008 and 2010 was smallest in Europe and Northern America which are the continents to put biggest stress on innovations. [25] According to the Swanon Law the doubling of cumulative shipped volume causes the decrease in solar photovoltaic modules' price by 20% [26] which is a very optimistic prognosis. Keeping in mind that silicon panels are already 60 years old and little improvement was made within last 10 years [27], we may look forward to the development of organic photovoltaic modules. However, due to their little efficiencies, change of characteristics and the need of frequent replacement, they are not suitable to be used on edifices yet.

The resemblance of organic solar cells and leaves is striking. They are both efficient for about a year, change colour during short life time and provide little energy which is only sufficient for a plant to survive. It seems that humans managed to succeed in achieving the nature's perfection. However, what is enough energy for a plant, apparently does not suffice avaricious mankind. Our willingness of merging architecture into natural habitat is, therefore, only seeming.

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APPLICATION OF DIGITAL FABRICATION IN ADVANCED CERAMIC BUILDINGS SKINS SYSTEMS

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The present proposal builds on the idea that, in the times of high performance demands regarding construction materials, ceramics may become one of the most suitable solutions for envelope systems. Due to earth capacity for natural erosion of minerals used for its production ceramics are highly sustainable. Furthermore, their characteristic such us durable finishes, thermal mass qualities, humidity control and material plasticity permit its application in high performance skin system. [1]

For a long time a use of ceramic coverings in architecture stayed limited mainly to a flat cladding, [2] but recent economic change implies a profound evolution of building envelopes. [3] Apart from featuring a wide range of technical and aesthetic functions (thermal, humidity regulation, lightning control etc.) façades are increasingly being explored as self-structured elements. [4]

Completed research concludes that ceramics, which early in their history (15th c.) have shown their capacities as an easy transportable “modern” material, [2] are nowadays fully competitive envelopes solution. However, in order to meet current challenges, both architects and ceramic industry, has to introduce recent technology in its design and fabrication. [5]

INTRODUCTION: CERAMIC MATERIAL CHARACTERISTIC

Ceramics have been used in architecture since the beginning of its history. [6] Although most likely they have been applied as decorative/finishing/cladding materials, there are some examples of its usage as a structural/self-structural element i.e. in Mesopotamian columns [7] and self-structural surfaces developed by Rafael Guastavino. [8] As a finishing they represent excellent qualities such as long durability, high resistance to wear, changing weather conditions and extremely high temperatures. [6] The reasons for its common usage in the interior surfaces finishing are, among others, easiness of cleaning and maintenance, anti-static characteristic and a good control of interior environment. [7] Mentioned qualities combined with exceptionally wide range of formal possibilities contributed, thought the decades, to continuous presence of ceramic tiles in architecture. Nevertheless, although the plasticity of the raw material allows nearly unlimited formalization, architectural ceramics has been mainly limited to flat tiles with a necessity of attachment to de primary structure. [6] The tendencies for three dimensional design appear relatively late and for the long time remain limited to modification of the wall surface, its deformalization without a deep change in a logic of ceramic tile applications, which remains a finishing layer attached to a wall. [9]

CERAMICS MEETING CURRENT FAÇADE MATERIALS REQUIREMENTS

Nowadays demands regarding construction materials went much further. With the growing ecological consciousness architects are forced to reconsider a huge environmental impact of buildings. Issues such as energetic performance, resources saving, local materials usage, and production optimization are main challenges of sustainable architecture. [7] In this panorama ceramics are highly competitive material. Firstly, the minerals that are used for their production are naturally reproduced. [10] Secondly, due to the facility in material acquisition, there were traditionally produced locally and so it could be today. [6] Although the embodied energy of material is quite high, capitation of the heat and its reuse allows for the optimization of production process. Their high resistance to the extreme climate conditions guarantees endurance in a weather events such as floods etc. and tolerance to the intense sun exposition. Furthermore their thermal mass characteristics enable a temperature control and can contribute to the reduction of city heat islands effect. [7] That upholds the theory that contemporary challenges as well as material capacities go far beyond the commonly recognized.

However, in order to fully take advantage of material qualities and promote usage of ceramics in advanced skin systems it is necessary to overcome some of its crucial limitations. The main disadvantage of ceramics is brittleness and low tensile strength [6] and consequently a necessity of primary structure usage. The other big challenge is an optimization of the production process including waste reduction. [11] Following passage aims to prove that those and other limitations can be overcome by incorporating the digital techniques into the process of design and fabrication of ceramics. Moreover they enable to explore greater material capacities, and go beyond what is commonly considered as architectural ceramics.

DIGITAL FABRICATION

Digital fabrication brings possibilities that can widely change the way of making the architecture. A direct programming of manufacturing and assembling gives architects a total control over construction process This then combined with the growing number of digital simulation tools and fast prototyping techniques enables a great freedom in the investigation on architectural forms and construction systems. [12] Deep understanding of those, still underused tools could open a way towards a new approach in ceramic facades design.

Prototyping

Barkow in his article for Architectural Digest underlined an importance of prototyping in the architectural design process. [13] Contemporary technology allows fast testing of design solutions and its improvements. Also Richard Sennett [14] in his Craftsmen claims that digital techniques "might serve as an emblem of a large challenge faced by modern society: how to think like craftsmen in making good use of technology". Prototyping is the first place where technology helps to limit the distance between the architect and final output of his design allowing him to take over a total control over designed element. [13] Probably the most important advantage of manufacturing methods linked directly with the design documents is an immediate response of the material while introducing the changes, this then allows a continues improvement the design itself. This importance of immediacy was also emphasised by Martin Betchold in the study of advanced ceramic shading system that will be described broadly in forthcoming passages. [15] Techniques such as 3d printing are recently becoming more and more popular as a prototyping tool, due to constantly growing accessibility of the printers. An experiment of Brian Peters from Design Lab Workshop architectural studio examines a possibility of creating customized structural ceramic elements by 3d printing. Although very time consuming process, does not allow to consider massive usage of such elements. [16] It proves that digital prototyping can contribute to development of desired ceramics shapes and helps to optimize it in order to overcome weakness of the material.

Customization

According to A. Zaera-Polo (founder of Foreign Office Architects), both environmental and economic changes demand the profound evolution of building envelopes. "At a time when energy and security concerns have replaced an earlier focus on circulation and flow as the contents of architectural expression, the building envelope becomes a key political subject". [17] Contemporary facades contain growing number of functions, starting from control over light, heat and cold flow and responding to changing climate conditions, up to energy collecting systems. [18] Apart of environmental issue, Zaera-Polo is underling the socio political importance of the building skin as a transition between public and private, and a main medium of building's identity. [19] In this context, formal capacities of ceramic are accurate response to occurring needs.

At the moment ceramic industry in majority uses "large hydraulic presses and steel molds to form flat tiles from dry clay bodies". [20] This production method does not allow creation of three dimensional modules and significantly limits formal possibilities. Published in 2012 King's and Bechthold's study reports that there was only one company in Spain, 1st ceramic producer in Europe, [21] able to produce customized 3d ceramic elements. [22] More advanced technique – forming by extrusion is being used by smaller number of manufacturers and gives more possibilities of form variation but as such remains very limited. [20] Design Robotic Group (DRG) at Harvard University in the cooperation with Tiles of spine has been conducting, throughout last years, several studies investigating possibilities of engaging the robotics in ceramic production process. The flowing matter study by GSD students Stefano Andreani, Jose Luis Garcia del Castillo and Aurgho Jyoti examines integration 6-axis robotic arms equipped with the cutting wire tool into an extrusion process. [23] Although the aim of mentioned study is construction of bear-loaded walls, it explores the customization capabilities that could be applied for ceramic envelopes components. Authors of the research conclude: "The result is a fast, economic, and efficient way to fabricate highly differentiated ceramic components with the use of robotic technologies". [23] In refer to the same investigation. Bechthold claims that the applied method results in an unexpected richness of forms that are accurate for both structural and non-structural surfaces construction. Taking advantages of structural qualities of created pieces could contribute to reduction or even elimination of primary structure, so far necessary in ceramic envelopes system. Final output of the experiment is creation of complex curved, ruling surfaces instead of planar elements commonly constructed from ceramic elements. [24]

Another study o Harvard's DRG examined the use of simulation and physical measurements in creating highly performative ceramic shading system. Apart from the parametric design process of an optimized shading model, there was a novel digital workflow proposed. Examined solution allowed avoiding usage of individual, single-use molds, that normally would be necessary to achieve a desirable customized tiles shape, what consequently would significantly increase manufacturing costs. Instead, the robotically actuated mold was designed, that directed from rhinoceros script would change its geometry from tile to tile. Afterwards the raw material was deposited using a robotic arm. [15] Betchold emphasizes that novel fabrication method may respond for still unresolved necessity of customization in architecture. Furthermore usage digital simulation tools allow merging environmental and esthetical desires into one project. [15]

Assembling

Achieving curved surfaces as well as design of complex envelope pattern reveals another challenge of customized ceramic elements usage. Represents of the Spanish tile industry declared that there is a significant disproportion between constantly evolving production methods and traditional manual installation method that may be highly exposed to mistakes. [22]

Furthermore the cost of ceramic tiles installation significantly increases the price of final tile finishing/element, and is very time consuming. While the number of highly qualified, skilled craftsmen is constantly decreasing, [22] there is a growing tendency to investigate sophisticated, operative envelope patterns. [19] Among other examples, FOA, Spanish Pavilion at Aichi Universal Exhibition in Japan from 2005, Tadao Ando and Olafur Eliasson facade of Tokyo Jewel Box or Herzog and de Meuron Museum der Kulturen in Basel from 2010 are definitely worth mentioning. Zaera-Polo argues that “the geometry of the tessellation is crucial to determine its various performances: environmental, iconographic or expressive”. [17] In order to enable maximum freedom in designing desired facade output, the difficulties of assembling process must be overcome.

Another study of Harvard’s Design Robotic Group investigated a customized robotic tile placement. [22] Conducted experiment examined programming and robotic assembling of tiles different in format using priory written algorithm and complex image based mosaic creation and concludes that, although the cost of traditional and proposed assembling method are similar, robotic placement enables achievement of more sophisticated patterns that could not be realized manually. [12]

Probably the most significant example the robotic ceramic placement is the facade of Gantebein Winery in Flash, Switzerland designed by Zurich based Gramazio&Kohler architecture practice delivered in 2006. Concrete skeleton is filled up with bricks that serve for temperature balancing – using thermal mass qualities of masonry. Digitally design pattern, with the specific rotation of each brick, enables desirable light and air flow, necessary for the appropriate interior conditions. At the same time skin does not allow for an unwanted direct sun radiation. While controlling environmental issues façade meets high esthetical demands with the variety of lightening effects achieved thanks to irregular brick placement. Architects emphasize that using robotic assembling method that is controlled directly from design document, they were able to use maximum of the time for developing the project until facade was being constructed. [25]

Beyond material capacities

New York based Centre for Architecture Science and Ecology [26] is investigating advanced architectural solutions focused on sustainability since 2008. Among other experiments, they developed a ceramic screen wall system that could be applied in extremely hot climate. [26] Parametric design of the geometry of ceramic modules was conducted in order to minimize temperature gain during intensive sun exposition in the summer and maximize it in the winter, taking maximum advantage of the thermal mass characteristic of the terracotta and maintaining comfort temperature in the interior. The structural qualities of the material were improved by adding glass fibres into traditional terracotta composite that significantly increased a tensile strength of the assembled wall. [10]

Studies like this prove that traditional material such as ceramics combined with advance design tools and innovating thinking can results with an outstanding outcome. Vollen [1] confesses "Several large architecture and engineering firms have expressed interest in using the product in upcoming projects." Following passage presents the case study that is an example of successful application of advanced ceramic skin system in constructed building, which proves long lasting capacities of ceramic envelopes solutions

LISBON AQUARIUM EXTENSION AS A STEP TOWARDS THREE-DIMENSIONAL CERAMICS

Delivered in 2011 Lisbon aquarium extension, designed by Campos Costa Arquitectos is one of a few realized projects with the usage of 3 dimensional ceramics in performative facade system. Building envelope made of 5000 ceramic was created in response to environmental challenges. Carefully designed, changeable permeability of the skin allows the natural ventilation and serves as solar shading, provides the semi-open coffee shop zone with sophisticated lightening effect that change during a day. All the pieces are slightly distinguished in colour which adds a delicate vibration to overall facade output. Pedro Campos Costa emphasizes that the decision for the material followed an identification of the specific needs, regarding both the building itself as well as particular site. [27] One cannot forget the importance of Portuguese context that carries a long history of architectural ceramics usage. [2]

The customized ceramic tiles elements were developed in the close cooperation between architect and Spanish tiles manufacturer Cumella. The importance of the constant contact with the producer is widely underlined by the architect. Initially all ceramics were supposed to be three – dimensional, although prototype of such was developed and proved the feasibility of a solution, it could not be realized due to a budget constraints. [27] Final facade is consisted of the openwork part, and corners made by 3D pieces and the closed parts of the screen wall made of flat tiling, which however brings the sensation of depth by the slight adjustment of the tile surface. Although production methods used in that project were traditional ones, it proves the growing necessity of customized facade solution. Furthermore 4 years long history of the building stands for long lasting qualities of the material that doesn't wear any marks of the time so far.

CONCLUSIONS

Presented studies build a panorama of possibilities enabled by rethinking the traditional ceramic usage in architecture. Investigations in digital fabrication method application for production of facade elements open a way to novel utilization of the material. Although almost in every case further research is needed in order to successfully incorporate such methods in existing ceramic industry, they respond to an increasing need of customization of architectural elements. Environmental criteria can be applied from a very beginning of the design process by usage of the growing number of parametric design tools. Digital tools allow the exploration of formal and performative capacities of ceramics that would be impossible with traditional manufacturing and design tools.

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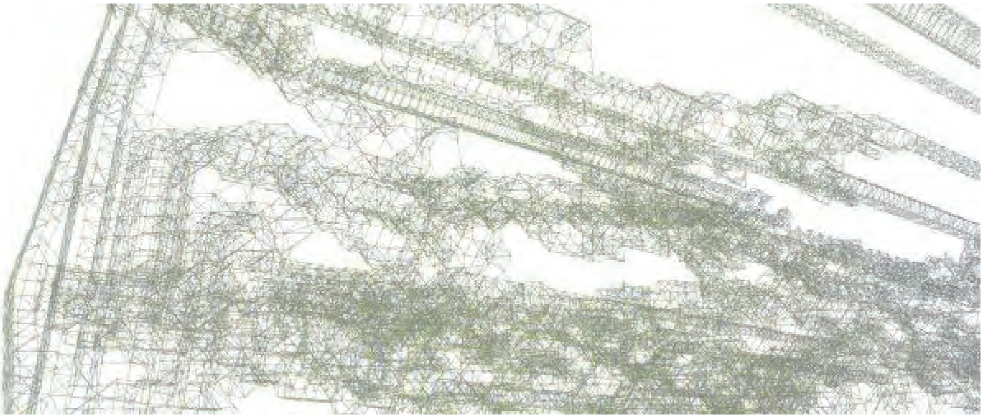
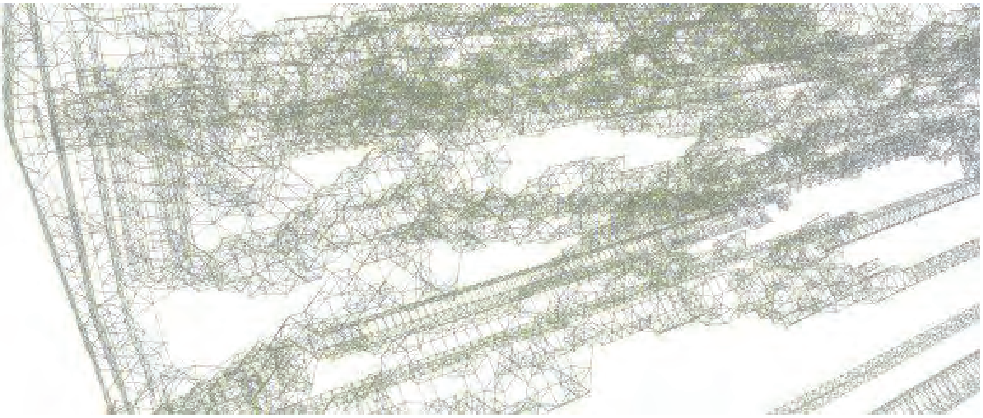


URBAN STRUCTURES



MODELLING INNOVATION DYNAMICS IN URBAN STRUCTURES

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This paper outlines the research topic of the spread of innovation and knowledge in space in general, and in urban spaces (cities) in particular. It synthesises work carried out with the use of cellular automata and agent-based models, as well as recapitulates knowledge on knowledge environments dynamics. The paper also presents new research input revolving around the attempts to calibrate the aforementioned model types in order to make them able to recreate real-life, historically accurate, and measurable phenomena from the realm of idea/knowledge diffusion. The paper includes the summary of how, in order to achieve that, a more detailed and data-related approach has been taken concerning the issues of agent behaviour and spatial environment description. The presented report is concluded with an outlook on future work on the various models and with the invitation to offer feedback and suggestion to the authors.

BACKGROUND

This paper addresses the question of whether the emergence and growth of innovations in urban spaces can be predicted. The study presented here is a part of an ongoing research conducted by the Technische Universität Dresden, Wroclaw University of Technology, and Toyohashi University of Technology, which focuses on recognizing knowledge environments and knowledge dynamics. Acknowledging the nature of innovation emergence and diffusion may be of significance for urban planners, city authorities, and researchers interested in spatial planning.

KNOWLEDGE PROCESSES AND DYNAMICS

Diffusion, spread, and transmission of knowledge in space over time is the main interest for the authors and the core of the research. The phenomenon of diffusion can be viewed from two perspectives. One view differentiates expansive diffusion from relocative diffusion, while the other juxtaposes contagious diffusion and hierarchic one. [1]

Expansive diffusion only transfers the idea or phenomenon to another point in space. A simple example may be mailing between people, which is clearly able to transmit ideas.

Relocative diffusion, on the other hand, requires a material carrier of an idea or phenomenon to be physically moved in order to spread. This type of situation applies for instance when a teacher or messenger meets other people and introduces new thoughts or modes of behaviour to the travelled area.

Relocative diffusion may also involve machines or other objects, whose implementation in a new place equals the introduction of a new idea there.

Contagious diffusion describes scenarios in which the spread of an idea or phenomenon is continuous in geodetic terms or, in other words, covers an area more or less gradually. This can be imagined by way of weather reports, most notably in times of a change of atmospheric fronts. Finally,

Hierarchic diffusion stands for a “leaping” idea or phenomenon, i.e. for situations where the spread is punctual. This may be observed with ideas that are carried between particular places in space and/or particular groups of people, e.g. academics, artists, followers of a religion, or generally focused groups with shared interests.

The four types of diffusion most frequently overlap and mix and are not necessarily easy to distinguish. That is especially true for urban conditions, where the multitude of persons and interests, the differences in world view, and the times of globalisation make the tracing of the spread of ideas much more difficult. [2]

A knowledge environment could be simply defined as an environment where knowledge “occurs”, i.e. physical space where science, creativeness, and innovation meet. Defining the conditions for knowledge transmission or innovation emergence (i.e. environmental settings), better understanding of those mechanisms, and recognizing the rules shaping those processes allow for forecasting of innovations emergence in a specific space, such as urban areas (cities). Therefore, two main concepts should be explored:

(1) environmental settings – which areas are most suitable and attractive for the knowledge-carriers?

(2) knowledge-carriers – how do they behave, interact, and what are their settings?

With understanding of these elements, a set of rules describing innovation emergence can be established. It seems fair to say that a combination of Cellular Automata (CA) and Agent-Based Modelling (ABM) might operate on such factors best, as they provide possibilities for integrating spatial settings with dynamic processes.

The pioneers of applying the cellular automata to urban planning were Chapin and Weiss at the University of North Carolina in the early 1960s. In their model, cells were representing the components of settlement and assigned degrees of attractiveness to neighbouring cells according to adjacency relationships (Chapin and Weiss 1968). The idea was further developed in 1970s by Tobler [3] and Albin. [4] The definitions say that a cellular automaton consists of a regular grid of cells where each cell displays one of a finite number of states. They transform in the (discrete) time according to transition rules. The transition is based on a current state of a cell and the states of neighbouring cells. As it was highlighted by Wolfram in 1986: *Cellular automata are systems of cells interacting in a simple way but displaying complex overall behaviour*.

An analysis of the issue of cellular automata has revealed a large number of algorithms and models used by different scientific disciplines. In the context of research on spatial development, there are many models focusing on urban development and two institutions seem to be particularly outstanding: Bartlett School in London (with Michael Batty) and the Centre for Connected Learning and Computer-Based Modelling, Northwestern University, Evanston, IL, led by Uri Wilensky.

Combining cellular automata with other models is a relatively new idea that emerged in the beginning of the XXI century. The most popular way is to combine cellular automata with the multi-agent systems, but attempts were made to combine cellular automata with the Monte Carlo method, the Markov chains, or with the artificial neural networks. Multi-agent systems are based on *representing objects and populations at an elemental or individualistic level which reflects behaviours of those objects through space and time*. [5] Those models are usually seen as a next step in the urban models future. The main feature and advantage is to represent objects or people in an elementary way with the use of individualized units, so-called agents. Behaviour of agents can be based on fairly traditional rules, but usually it is based on the relations with the environment (cells) and other agents. Multi-agent systems are based on a «bottom-up» approach and often show the emergence of more complex systems. Those models focus on the study of various dynamic phenomena occurring in urban areas e.g. migration, cooperation, transport, etc. The first urban models that were built in the 60's were relatively highly aggregated and thus relatively simple. Nowadays, multi-agent modelling has lower aggregation and greater heterogeneity. Of course, this raises the question of the degree of the model generalization. However, it seems fair to say that cellular automata (and related models) might be useful in predicting the urban phenomena on various scales. [6]

Given the tools (CA and ABM) and having in mind the two concepts described above, we could start building up a model to forecast the innovation emergence in urban spaces.

MODELLING INNOVATIONS

Understanding relations between knowledge and environment, and the ability to comprehensively model these processes is a complex task where relatively large number of factors, features, and conditions should be taken into account. Therefore, the conceptual framework for the research consists of several rules and states describing the environment (cells) and individuals (agents). The software used for the research was the NetLogo programme, as it allows for very personalized model-building with the use of a rather simple programming language.

An initial version, dubbed “1.0”, was built in order to test the basic features of both the software and the model. In principle, agents (ideas/innovators) look for cells (locations) where they change the cell state (‘set up’ an innovation). The modelling space was an abstract, arbitrary square area; its environmental settings consisted of four (‘two-by-two’) types of cells: road and non-road; and centre and non-centre. These cell types were attributed with attractiveness ratio: the central location is more attractive than the non-central one, and only the ‘non-road’ type cell is possible to be settled. The cells could display two states: regular and “innovated”. The attractiveness was codified by the map colouring and if it was high enough, the cell was subjected to the process of innovation. This was set up in order to represent the situations where agents (understood as potential business owners looking to start a business or existing business owners looking to expand their domain) go through the real estate market in search of a fitting location for their activity. The necessary other understanding of this rendering is seeing these business agents as innovators – simply by assuming that a portion of the newly set-up business activities could be called innovative. In the model, agents were given the following settings and attributes: initial energy (capital), cost (of movements), profit (earning energy/capital), and the minimum value of energy 'to innovate', i.e. to change the cell state from regular to 'innovated'. The agents were allowed to travel across the grid and innovate if specific requirements were met (enough energy/capital for innovations/setting up a business). Due to the promising results of the initial modelling, an improved version "2.0" was built, where more features were applied. The new version lends itself to the theory of living systems more and allows for more adjusted simulations. Agents were attributed with more characteristics, e.g. reproduction energy threshold (representing the spread of knowledge). Furthermore, agents gained the ability to "upgrade" if particular conditions were met. 'Innovated' cells were subjected to 'aging', given the assumption that innovations do not last forever and become less attractive over time. It is possible, among other scenarios, to take the model to the situation where the resources would wear out due to the cheapness of action and the number of agents rise to the point of overcrowding, then it would diminish because of that, and then again rise – just as the systems theory describes the pattern of behaviour of food chains in the animal kingdom. [7]

The model is aimed at contributing to a better understanding of knowledge processes, and also to the work towards the ability to predict the emergence of innovation in urban spaces. However, more studies need to be undertaken in order to develop the model and increase its accuracy and reliability.

FUTURE WORK

The model describes knowledge dynamics, namely innovations, in urban spaces. It seems fair to say that the tool is promising and worthy of further development. In the future work, several challenges should be addressed. The model should take into account factors such as density (of coverage of an area by a phenomenon), frequency (of occurrence of a phenomenon), intensity (of impact of a phenomenon on an area), absorptivity (of an area to accommodate a phenomenon), probability/chance (of a random change in conditions), and others. The problem of the attractiveness of a cell needs further consideration with respect to population, surroundings, number of universities in the vicinity, technological supply, labour quality and number of university graduates, number of competitors, and more. The set of parameters characterising the agents could be also enriched by investigating economic conditions (founding capital, travel cost, earning profits, capital necessary to set up a business), the third dimension (height of buildings), decay (of phenomena or of material structures; relating to the theory of living systems), social behaviours (collective). Most importantly, simulations of real areas should be conducted in the next steps of the research. Therefore, concrete data must be gathered, e.g. real estate value, infrastructural proximity, centrality, university neighbourhood, competition in the area, etc. Among the multiple remaining research questions, a prominent one is that of the calibration of models, i.e. whether it is possible to calibrate a model in such a way that it is able to recreate real-life, historical developments with satisfying precision. This approach has been tested throughout the history of cellular automaton and has had success, however it has never been perceived as sufficient. This means that even an accurate calibration of a recreative model must be viewed as only a part of a research, and not an aim of it.

CONCLUSIONS

The preliminary results indicate that the knowledge dynamics in urban spaces are possible to be modelled, provided several conditions are met. The Cellular Automata combined with the Agent-Based Modelling seems to be a promising tool for such simulations. Crucial factors, including social behaviours and business strategies, can be parametrised and incorporated into the model with respect to geographical settings and spatial conditions. The research will be continued in order to better depict complex knowledge dynamics. Forthcoming results may be of importance for urban planners and scientists dealing with the spread of innovations, as they may include contributions to investigations on space attractiveness, urban area settlement processes, and even single building-scale research.

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DESIGN AND CONSTRUCTION OF PARAMETRIC URBAN FLOOR, AS PART OF THE REVITALIZATION OF THE CONCEPT OF POWSTAŃCÓW AND SOBIESKIEGO STREET IN RYBNIK

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The completed parametric floor project for Powstańców and Sobieskiego Street in Rybnik was developed by the author in 2013-2014. This paper describes the method for forming principals in the revitalization of downtown Rybnik. Decisions regarding urban scale became guidelines for the design in the scale of the street, square and urban detail. This article describes how digital design tools were used in the stage of building design and the construction phase.

THE HISTORY OF THE PLACE

Rybnik was a fishing village lying at the crossroads of important trade routes. From the earliest phases of the development of the city, a built-up central area has covered the space between the market and today, the streets of ul. Powstańców and Sobieskiego. At the beginning of the twentieth century, at the fork of the streets Powstańców and Mikołowska, St Anthony's, the largest neo-Gothic church (now Basilica) in Upper Silesia, was built. This marked the beginning of one of the most important axes of the city, acting for many years as the "high street". In the last decade, after the construction of two shopping malls in the city centre of Rybnik, the most important historical city trade route lost its importance. Stores gradually turned into vacant premises and the members of unsuccessful campaigns of participation completely lost confidence in the government. Unwanted traffic impropriety and repeatedly patched pavement degradation caused the condition of the streets to gradually deteriorate. The situation required the intervention of Rybnik's authorities.

THE PURPOSE AND CHARACTER OF THE DEVELOPMENT OF THE PROJECT

The aim in the course of the project is to stop this process of degradation and demarcation of the area, designed to lead towards re-activation. A multi-disciplinary regeneration concept was founded that has been subjected to public consultation. Studies of the urban scale provided guidelines towards the necessary changes of traffic movement and guidance to projects on a smaller scale. One of the elements was that the development of architectural and urban intervention could be used to carry out activities that would attract people to the revitalized part of town. Also important was to change the image of the place into one that again interested investors and entrepreneurs, as this purpose is crucial for the functioning of the area in the long term.

A CASE STUDY IN THE CONCEPTUAL LAYER

Author's design solutions

(I) Changes in the traffic system

In accordance with the principle of merging friendly city residents, with a strong local economy, an element of pedestrianization has to be introduced. The elimination of the vehicular traffic that separated the Basilica of St. Anthony from ul. Powstańców, as well as the latter, linking it with Rybnik's market square - a key solution for the design. The dominance of the new transport system has been handed over to pedestrians and cyclists. Public transport has privileged use of the area and there is an allowance for limited private car use. Through traffic has been eliminated.

(II) Promenade

The aim of the functional division of the pedestrian zone was to ensure maximum exposure to sites, and equal access to space devoted to commercial activities (eg. gardens, cafes). The width of the pedestrian zone has been divided into three bands. First, (about the width of four meters), a pedestrian route with occasionally authorized one-way car traffic. The middle band of variable width, is named the zone of activity. This has a dimension similar to the first band. It is a place for businesspeople, but is also an important area for cultural and social action. The third band, about the width of two meters, is only for pedestrians. The banding is selected during the drawing of the ground surface. On the border of the zone of activity and the southerly located band are street lights, fixed seating and junction boxes with the means necessary to power the activity zone.

(II) Place

The promenade is divided into short sections. It involved the creation of attractors, which not only create the mental impression of a shorter distance of the whole route, but also attracts people to the high street. The five sites are designated "places" - areas of special features, highlighted by the changing figure of the ground surface. The names reflect the traits and composition of these spaces: Plac Wejścia. (Entrance Square), Plac Światła. (The Square of Light), Plac Przejścia, (Transition Square) Plac Opowieści (Square of Stories) and Plac Wody (Water Square) (see fig. 1).

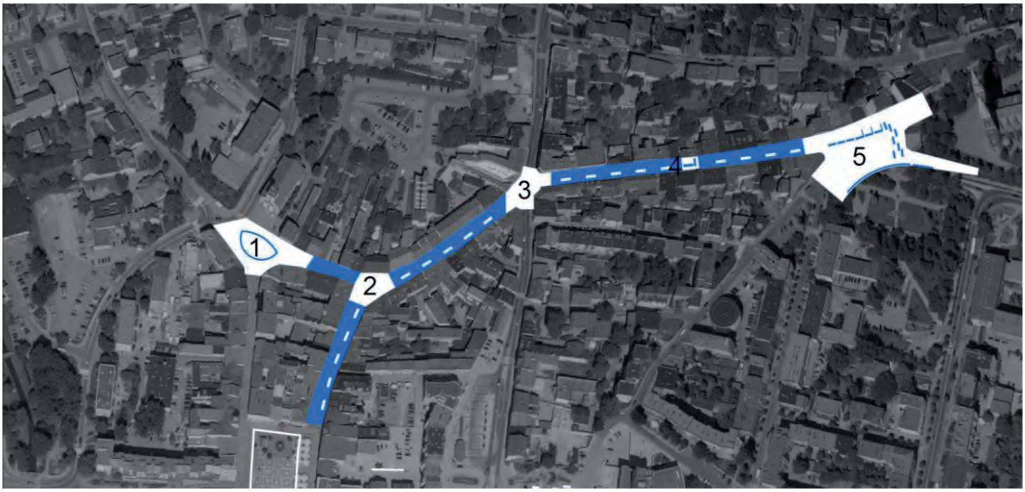

Fig. 1. The sections of the promenade: Plac Wejścia. (Entrance Square, no. 1), Plac Światła, (The Square of Light, no. 2), Plac Przejścia, (Transition Square, no. 3), Plac Opowieści (Square of Stories, no. 4), and Plac Wodny (Water Square, no. 5).

The places are enriched by the unique elements of landscape architecture and spatial installations. The attractiveness of the system will determine if they are points where people will want to come, by means of activating the entire length of the street.

(1) Plac Wejścia

The square in front of the church of Our Lady of Sorrows is located, near to the market square, a point defining the beginning of the pedestrian area from the west. In the future, an extension of the square in the direction of the university campus is planned. A large oval bench has been designed around the statue of St. John, upon which university students and other residents can gather.

(2) Plac Światła

The square at the intersection of Sobieskiego Street and St. John's Street during the day, is illuminated from three directions: east, south and west, the rays of the sun shining between high buildings. This gives a variable and very interesting lighting system. In a place easily visible from all directions, the spatial object of transparent and reflective permeable materials reflecting this sunlight and provide a visual interaction with solar rays. After nightfall, laser lights coupled with motion sensors are set to run. It is possible to use different sequences of lights, and even control access to them via the internet.

(3) Plac Przejścia

Pedestrians cross the busy street of ul. Gliwicka. The extension of the pedestrian area of the entire intersection here, and its elevation relative to the road surface, combined with the traffic lights, is primarily to ensure the safety of those travelling on the promenade. This also optically connects the eastern and western sections of the road.

(4) Plac Opowieści

Halfway between Plac Przejścia and the basilica, the narrow street of Powstańców does not allow for a vast variety of activities. Previously, this place allowed for more, but the needs of the area have spread over a number of years. A multimedia device is to be installed in the central part, through which pedestrians will be able to read short stories, connected with a wide variety of topics related to the city.

(5) Plac Wody

John Paul II Square, in front of the basilica, as a result of differences made in traffic organization, has changed from a traffic junction to a target route point. Along with a modernized, adjacent square, it is intended to serve the purpose of walks for residents and tourists. The project uses and emphasizes the advantages of this place: the monumental figure of the church with a lookout tower staircase with a view of the city and also incorporates the characteristic slope of the surface.

An almost 60-meter-long bench has been designed at the junction of the square and the park. In the center, in a lowered floor, a computer-controlled fountain is housed. About 50 nozzles in different sequences emit jets of water. Each stream is lit and the effect is completed by the synchronicity of light, sound, and movement.

Supporting activities

The activities on the promenade should support the gradual modernization of the whole area. Alternative passages and alleys, and other courtyards off the main street should be renewed.

Even the most expensive modernization does not ensure success in the form of a peoples' return to the old trade route. What is needed is to change the structure of trade and services. The right direction seems to be dining and specialized shops with offers for customers. Trading hours must be extended. Many passers-by after dark head in the direction of Plac Wodny for light and sound shows.

On the side of trade and non-governmental organizations, as well as some municipal institutions, development opportunities are offered by the range of activities on the promenade. With ideas that suggests the concept, it is worth mentioning seasonal flower shows, antique fairs, books, local agricultural products and confectionery, ice sculpture competitions, etc.

Only comprehensive and multi-threaded activities can ensure success, so it's important that contributing to the revitalization program is done by many people and institutions.

A CASE STUDY IN THE LAYER TOOL.

Parametric design tools have been developed to accelerate the design process and provide maximum control over the project's complex geometry (see fig. 2).

Development of the geometry of road

The new surface geometry had to integrate functional division routes with the technical requirements of the urban surface. The most difficult point was Plac Wodny, in which four directions intersect, creating an area of considerable sloping. It was at this point that the interactive water system was to be located. The very form of the fountain was to be integrated into the ground in such a way that the beginning and end of the fountain were not noticeable.

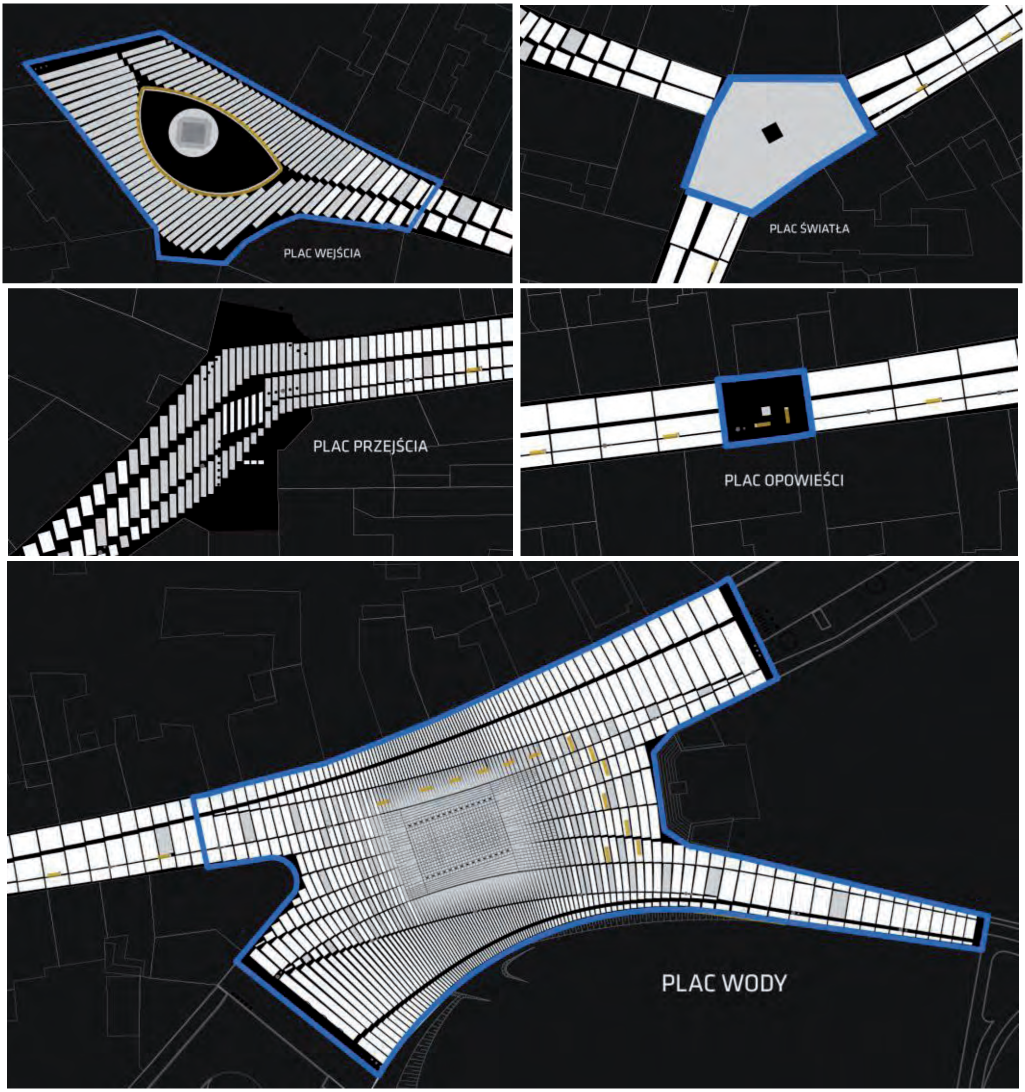

Fig. 2. The new surface geometry of the 5 squares.

Flattening the surface of the fountain, allowing for closed loop water fountains and the control of rainwater, necessitated the creation of a new sloping surface. As the movement of people had to be both easy and secure, this required the elimination of strong declines. A tool has been developed for the project that, at any resolution, could describe the direction and degrees of decline of the complicated surface. In addition, the tool showed, the difference between the old and the projected surface of the square. Any change in geometry automatically generates all the drawings describing the characteristics of the proposed surface. It was therefore possible to meet these two seemingly mutually exclusive terms (see fig. 3).

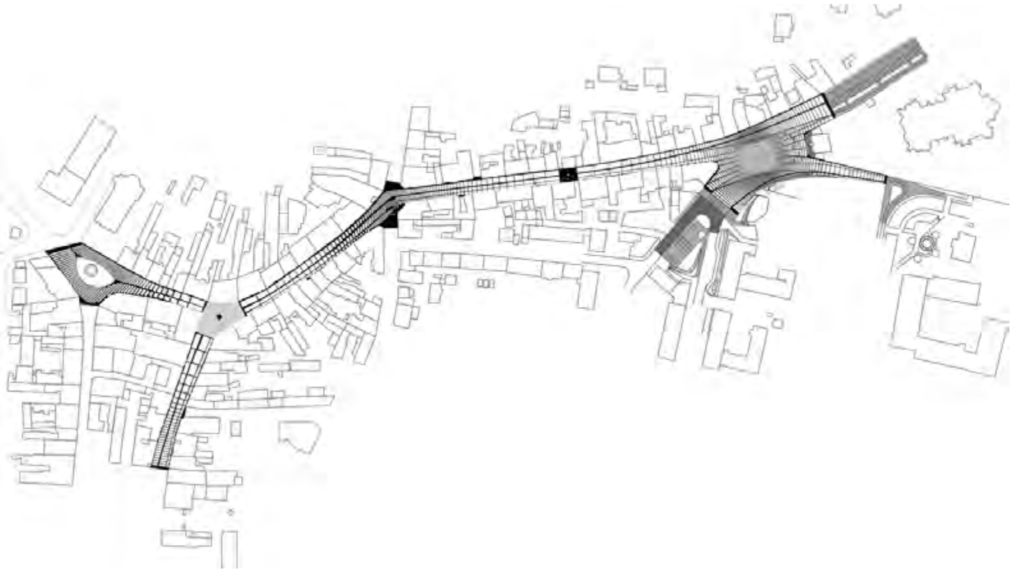

Fig. 3. The design of the whole promenade.

Development of the apportionment formula

The basic divisions resulting from the formation also provided the framework for the distribution grid floor. The difference between the sectioned squares and roads was emphasized by a thickened and thinned distribution of the fields. The density of the distribution was controlled by the graph function. However, this variable division had to be adapted to two guidelines: integrating the varying floor surface with the regularity of the distribution of fountain tiles and the size of plates forming the basic module surface. Non-rectangular irregularities arising from the division of outlines and have been filled with small-sized elements allowing for the development of irregular shapes. However, the cost of the finished surface of these small-shaped elements was larger than using bulky items. Therefore, the challenge was to find such a function controlling the distribution grid, which minimized the number of these elements and as a result, reduced the cost of the pavement.

The problem can be reduced to the question of entering the largest rectangle in the quadrangle. In addition, it was important to ensure minimum and maximum distances between fields. Different types of algorithm were tested, which implemented these conditions. The algorithm has been modified, which implied a change in the pattern of the whole surface. This issue is unusual for the architect's workshop, but translates directly to the materiality of the project. Although all aspects of the design can be parametrized to be described in such a way that there were only general assumptions of pattern. These drawings, which make it easier to do in a traditional way, were not generated.

The struggles involved in this project (see fig. 4) are characteristic of projects which are created using processes, or sets of processes, rather than projects done in a traditional way involving direct decision making.

Fig. 4. Visualization of the Plac Wodny design.

The designer, setting out the principles of the process, can be surprised by the result of their decisions. The experience gained from such a tight-knit process can in fact hinder the ability to assess the aesthetic of the product. Possible changes within the accepted parameters are very easy, but changing the rules is much more labour-intensive than in the case of the direct drawings.

COMPLETION

The pedestrian opening was a spectacular success. Attendance at evening shows, fountains and the opening event "wdepnij na deptak", positively surprised everyone. From that moment, a number of new premises were established. At the same time it should be noted that only some of the revitalization concepts have been implemented so far (see fig. 5). Some elements were carried out by independent designers who, unfortunately, were not familiar with the overall vision for the whole revitalization process. The quality of the construction work was often noticeably far from the design. Further actions related to activities in this particular area are not currently known.

I moved into an apartment overlooking Plac Wodny. All the deficiencies in the art of construction, I see every day, and it is not optimistic. However, when children are running around the fountain, as soon as the sun is stronger and people are sitting by the fountain, while the rest of the city is empty,

Fig. 5. The comparison between previous (left) and current (right) state of Plac Wodny.

All pictures are created by Karol Wawrzyniak and this article is based on his own experience.

POTENTIAL OF (AGENT) SOFTWARE SUPPORT FOR PUBLIC INVOLVEMENT IN SPATIAL PLANNING

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Nowadays, parametrical design tools are becoming a breakthrough in architectural geometry design. However, they seem not to be much of use in urban planning. The exception could be Agent-Based Modelling Systems (ABMS), mainly because of its modelling type-based on various (also contradictory) rules on different parts of the same system.

This gives hope for the rationalization of the planning processes, which are not based on pure cybernetics, but on the current negotiations between lobby groups, governments, media, social activists, investors and other groups – actors whose interests might be conflicted.

ABMS is not a new method, however; the existing software is equipped with interfaces that allow its use in new fields where significant results are expected: in revealing the convergence of action-makers and interest groups, including the process of planning the most capricious and unpredictable ones - in public participation processes.

INTRODUCTION

Urbanism has little to gain via parametric design – at least on those of its elements, which today belong to the mainstream avant-garde architectural design. This sceptical conclusion does not come from ignorance for the new tools, but from a simple statement that the observed breakthrough in the parametrical design relates almost entirely to the geometry optimization techniques improvement. While in architecture and building constructions it is an important aspect (often even the most important), in urban design (even more so in regional planning) more important than the geometric parameters are those describing the dynamics of designed systems.

Our team, as a part of the research on the inclusion of elements of environmental medicine in optimization systems of urban environments, was also working on the potential use of ABMS. One of the areas in which we have observed a very serious potential (measured with potential effects) turned out to be the use of ABMS as:

(1) tools to collect useful information about the preferences of individual users of different spaces and urban systems,
(2) tools to present results of urban simulation (in the form of schematic animation).

The core of urban system dynamics planning

The city is a very complex system and this complexity has multiple levels. While many architects are still considering themselves urban planners, in urban planning more and more popular are becoming tools, which have little in common with architectural design.

Computer simulations in planning have been developing since about 50 years and were innovative in the 1960s. The concept of object-oriented computer languages (like Java, Python, and other which are basic today) comes from simulations laboratories (frequently from ones dealing with space).

Modern techniques of planning rather orbit around the universal systems theory, complexity theory, self-organization theory, and other phenomena invisible or unimportant for architects (perhaps due to seeing them as outlined not clearly enough).

In large scales, functions and movements count, not shapes

In the urban scale, the quality is evaluated based on functionality, the level of satisfied needs, and other factors that cannot be assessed based on shape or aesthetics only.

Indeed, some attempts to design cities based primarily on geometrical shapes were sometimes taken; sometimes even with the use of new software. Such projects rarely get into the implementation phase, and they are finished even

more rarely. Usually the culture in which they arise, they rather have a similar function to the monuments erected for authorities.
While for the architectural forms, the evaluation criteria of aesthetics (incl. based on the modern logic of form) are important, whereas in the urban system the use of the same criteria for the evaluation seems useless, and often also costly or even harmful.

“Shapes of logic” is not a concept capacious enough to fit the criteria evaluating the quality of the city, nor even larger settlements. Not every designer can handle the distinction of evaluation based on scales.

However, the most important change required to proper and possibly full assessment of the quality of urban project is the ability to assess the impact of spatial changes on the quality of the functionality of different subsystems (road, rail, power, and others) and to assess the impact on quality of life noticeable for individual users of the space.

It can be said without any exaggeration that a detailed assessment goes beyond cognitive possibilities of a single person. The best specialists are characterized rather by ability to choose those, which later turn out to be the most important, rather than by the ability to track the highest amount of individual impacts and assessments.

However, despite all the problems associated with the evaluation of the quality of urban design, questioning the possibility of rationalization would be a mistake and an abuse. Especially an ethical abuse - due to the increasing knowledge about the impact of the various elements of urban environment on the quality of life its residents: on their health, life expectancy, physical shape, mental condition and other factors, the violation of any other method (except for the large-scale design) is considered a crime.

Quality evaluation criteria of the local plan: “it depends”

As it was mentioned earlier, the tendency for the geometry is not a virtue of an urban planner. Not in an urban planner’s work at least, as it may result with significant performance problems that have been ignored in favour of geometric clarity, visible only on maps.

On the other hand – it is difficult to focus on all these aspects while designing several subsystems with different internal logics at the same time (e.g. solving the problems of circulation system and pedestrian improvements, planning the network of local schools, the expansion of the sewer system, and localization of new recreation areas). The natural tendency of human thinking is to set priorities and to subordinate other components. Unfortunately, many projects have been focused on the solution of only one of these problems. Twentieth-century urban history is full of examples of urban devastation carried out in the name of improving the capacity of major roads and the construction of individual manufacturing plants.

Public participation: problem of planners, hope of planning?

In a kind of opposition to that "hiperspecialistic" attitude could be shifting a deciding vote to the spontaneously appearing social groups, focused on individual projects. This approach is mostly known as social participation and public consultation. On the one hand, it looks like a threat to the cohesion of urban plans, but on the other hand – it may work as a correction system for local plans from the perspective of their compliance with the expectations of direct users of the planned space.

Both of these (extremely different) ways of evaluation are neither fully right, nor fully wrong. However, they reveal the essence of urban planning: it IS a process of negotiation in which different actors are trying to achieve different goals. The problem is the majority of participants, do not know what negotiation is, or with whom it should be made. Who is the real decision-maker; to what extent (and how) an agreement with one of the parties shall be binding on other participants in the negotiations or how long the contract is valid.

These seemingly radical statements may look like a truism, if we take into account the fact that both the process of urban planning and investment, which relate to plans, are continuous processes. The city is a dynamic and a variable subject to planning only in certain areas. Carefully made compromises may turn out to be unrealistic plans that require urgent adjustments. Neither narrowing nor widening the group of decision-makers, do not guarantee an improvement of the quality of planning decisions.

Public participation was always and still is (more or less openly) criticized by environmental planners for allowing people to make decisions without proper preparation and knowledge that would enable a proper understanding of the space.

It is worth to point out that a complete submission of planning procedures to specialists is imaginably close to technocracy and – after a stabilization of the system - conceivably opens the road to totalitarianism.

In such circumstances, finding design tools which could support the consultation and negotiation processes in urban planning becomes even more important with a particular emphasis on affordability of interfaces and the way of presentation of data and results in a way which also makes them useful for the process of public consultation and public participation.

Crucial aspects of public participation

Public participation is usually based on transparent programs. The quality of these programs and their compatibility can be criticized, but definitely not the existence of the programs themselves. These programs are widening the group of allies who share a common goal. However, the creation of strong relations and allies who have contradictory aims can block planning intervention very effectively.

One of the weak points of participation, especially in the post-communist countries, is a lack of tradition (abilities than procedures) of developing wider civic alliances for which planning institutions would be desired partners. Multilateral negotiations, which take into account the voice of all involved sides, would clearly be targeted at commonly understood goals. It happens, therefore, that activists do not know – sometimes are not even interested – whether similar goals have been targeted in the past, with what results, and whether the conclusions drawn are still valid.

An impression could be had that in current planning systems, the role of planners in the eyes of participants boil down to a “black box”, while the role of participants in the eyes of planners is reduced to egoistic (frequently group) lobbying.

MATERIALS & METHODS: POTENTIAL OF USING ABMS IN PUBLIC PARTICIPATION

A significant hope for improvement of the state of affairs lies in a new generation of ABMS due to a particular ease in creating simulations based simultaneously of multiple logics relevant for chosen subsystems, and due to nearly free implementation of perspectives of assessment. Together with increasingly friendly interfaces and clear animations generated as results of planning agreement processes), it enables ease and transparent setting of priorities, as well as easy reading of simulation results, measured in ways applicable for each subsystem.

ABMS in the assessment of the state of processes and movements

The achievable level of realization of given functions for a given area largely depends on the fluidity of movements particular for these functions. Different movements (transportation) are required by an industrial zone and different ones are required by a residential area, etc. ABMS allows for easy defining of subsequent users of given areas – it allows for gathering of relevant data without the necessity of skewing them or adjusting them to the existing templates (i.e. it is very flexible in this regard).It makes possible conducting simulations of movements in which users are able to “identify” with various groups of agents. ABMS takes into account the multitude of roles (agents) in which a given person may appear – be it as a driver, a cyclist, or a immobile agent (at work or at home).

ABMS animations in show in a particularly clear way, also to non-specialists, the nature of the influence of planning and investment actions on achieved results. Statistical drawings (including photorealistic visualisations) do not render the essence of planning aims. Classic examples include attempts to explain to local communities the necessity of building a road, which is needed in order to bring down the traffic congestion on a different road, where local residents demand acoustic barriers. In such occasions, ABMS animations may prove helpful in explaining the matter and the reason behind the solution.

Taking into account the fact that ABMS is rather a rarity than a standard in the planning community, it is not surprising that planners frequently refer to city dynamics as to a mystery, while the participants of this mystery listen without understanding (in which, however, they often display alertness and common sense). Few planners are able to talk to non-specialists using an understandable language, without upsetting people, all the while evoking hopes connected to the plans. The dynamics of city movements seems to be one of the most challenging topics when relevant animations are not available.

The hope connected to ABMS is also anchored in the gradual improvement of the rules of assessment of city environments, measured by the quality of everyday life. A strong side of ABMS is the possibility to trace the history of subsequent “agents” (the so-called “line of life”). It is not a major problem to calculate how much time a resident of a given neighbourhood spends in traffic jams on his/her way to work. The gradual development of ABMS allows for hope for continuous approximation of the simulated phenomena to summarised assessment of the quality of life in given areas and spaces. Currently, among the more interesting trends are simulations of spontaneous recreational behaviours (understood as spontaneous reactions to creation of recreational areas in vicinity of residence), which clearly translate to physical and mental form of various users.

In the future, ABMS is very likely to appear in the role of a tool enabling non-specialists to participate in the adventure of creating the future of the city the live in; the adventure of improving their world.

RESULTS: POTENTIAL OF COMMON USE OF ABMS AND PUBLIC PARTICIPATION

Hopes

ABMS as a tool supporting the traditional formula of public participation – i.e. public discussion, mostly in groups of a couple of dozen people – may be a very good opportunity to narrow down and individualise “agents”. If, for example, the inquired information is what features of the quality of cycling paths are recognised by its various users, the users may be asked about it directly. Further, agent sets may be identified based on the gathered information. This way it is possible to separately outline the various subtypes of cyclists: children on their way to school, these same children on a bicycle ride, adults going to work, adults on a weekend excursion taking the same path to leave the urban area, etc.

A discussion directed at acquiring demands of individuals is becoming a discussion between two specialists – the cyclist identifies his/her choice of the route for work from among a safer path, a more silent one, a shorter one, or a more picturesque one. Information of that kind do not need to be averaged, which constitutes a major advantage of ABMS. Instead of convincing a group of cyclists that their views on cycling are wrong, it is possible to note down those views, introduce them into an agent set, and establish the count of this set (e.g. proportionately to other groups of cyclists).

The same discussion, in the same room, with the same people – but directed at covering a cycling paths system designed by an urban design studio – is, using a euphemism, less efficient, as it quickly morphs into a discussion of specialists with non-specialists, based on emotional arguments. *ABMS is perhaps the best instrument of gathering information on demands of non-specialists without the need of ignoring them.* Inclusion of content-related planning argumentation, in a form understandable for all sides, employing animations of variant situations, into the practice of public discussion (including in the media sphere) seems imminent: *what would happen if your (the public)* *ideas were implemented.* In the nearest future, a further improvement of the ABMS interfaces may be expected. That means an acceleration of popularisation of understanding for this method.

ABMS works with the lack of common theory covering various groups of agents and environments. It also means a significant potential for dialogue between specialists of various disciplines. Variant scenarios may be animated and assessed simultaneously for example for irrigation, forestry, vehicular or recreational systems. Consultations and planning work are possible without additional learning required from specialists of various fields.

ABMS is very well-suited for gathering knowledge on local conditions, such as data on local cultural particularities or characteristics of the use of given public spaces, including movements requiring the awareness of local rules. That may mean easiness in creation of, for example, pedestrian traffic w pilgrimage sites, where safety rules overlap with local customs. Another use for that could be the testing of effectiveness of voice commands (in various languages) for the needs of evacuation of large facilities (like arenas or airports) in which a multi-lingual crowd might be in danger.

ABMS modules may prove very useful in gathering local data for various planning actions; not only in creation of strategic and long-term plans, but also, for example, in designing traffic detours in such a way as to take into account particular needs of local users (such as a situation in which there is a user of a special vehicle which is not able to pass just any terrain).

The image of the planner – as a character accepting or rejecting social propositions without providing a rationale ("the black box") – could be gradually changed in favour of the role of a mediator and participant of planning processes.

ABMS is NOT a design tool. It will not pose good hypotheses for us; it will not provide guidelines for prototypical constructions; it will not suggest corrections of the prototypes being tested; it will not think for us. In this it is not *artificial intelligence*. When used properly, it is a proficient help in the assessment of complex results of actions which are in the phase of plans. ABMS simulations may be surprisingly resistant to distortions due to major factors, and equally surprisingly vulnerable to factors which seem minor. That sometimes means the necessity to adjust input data, and sometimes rethinking of the fundaments of specialist knowledge.

Conclusion

ABMS may be a good complement of existing simulation-design systems both on the stage of gathering of knowledge (acquiring and gathering data on the count and particular demands of various minority groups) and on the stage of presentation of results of proposed actions (proposed by specialists and lobbying groups alike). The usefulness and efficiency of ABMS in urban design has so far been confirmed only for modelling of vehicular traffic systems.

A key use of ABMS in the future may be rationalisation of collective disputes. That currently is the weak point of any major urban planning enterprise because collective disputes are based on human nature, which in larger groups is characterised by immunity to argumentation of the other side.

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CHALLENGES OF PARAMETRIC GIS ANALYSIS IN THE REDEVELOPMENT OF ILLEGAL SETTLEMENTS IN THE SOUTH EUROPEAN CITIES

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Since the cities in developing countries are constantly being forced to accommodate ever-growing number of migrating citizens, they struggle with the issue of illegal settlement as a result of authorities' lack of spatial control. [1] Projects challenging urban regeneration of these unrestricted areas face the difficulties of social resistance and issues of changeable constraints. Thus the design proposals require extreme flexibility, often reduced to basic principles that are difficult for further implementation for policymakers, developers and local stakeholders. In constantly changing and difficult to handle circumstances, the ability to reveal close to real-time mutable design proposals for urban redevelopment of mentioned sites seems crucial. [2] This research paper examines potential applications of parametric tools devoted to spatial analysis, to help identify problems and hidden possibilities of those self-formed urban structures in relation to the city as a system. It focuses on spatial integration in terms of equable accessibility to attractor spots, and proper distribution of public space within. It also elaborates the accessibility to GIS data based on open source providers like USGS or OpenStreetMap as variables animating the outcome of the design process; and highlights the ease of interpretation of the analysis results in terms of enacting derived principles.

BACKGROUND

Contemporary urban design faces new challenges in the 21st century. Urban development becomes more and more flexible, and functional changes more rapid. [3] Urban planners undertake public discourse on what the future planning would be. [4] And in contrary to A. Toffler's statement about western society that "they assume today's changes will somehow pass them by and that nothing will shake the familiar economic framework and political structure. They confidently expect the future to continue the present" [5]; one of the most prominent countries in terms of spatial order (the Netherlands) established, in recent decades, a variety of initiatives devoted to the issue of future planning with a lot of proceedings done - especially by former NAI (Dutch Institute of Architecture). [6] This discussion involves a range of specialists including policymakers, engineers, NGOs, landowners and such, who can all be called "planners". It focuses on the expectations of what the world of the future could bring and how can we prepare our cities and societies for that perspective. Since it is ever-continuing debate we cannot expect any final results, yet some vast questions arose from latest disputes. Above all, the need for new tools and organisation of work seems to be most essential for majority of contributors as it is rooted in the social desire for technology. [7] Regarding their point of view and global movement towards digitalisation of a design process, one issue is still valid; that not so many empirical research was done to implement existing tools into real practice. [8] Especially in response to the difficulties that developing countries struggle with: namely constant influx of new inhabitants into their cities with no restraint. It causes among many other reasons, the emergence of informal settlements that most commonly are attributed with poverty, social exclusion and crime. [9] And as global researchers from UN Habitat, Space Syntax, or Senseable City Lab point out, it does not addresses only the poors of certain societies (as applicable to India, or South American countries) but it includes also those who decide to undertake the design process without proper permits and formal establishments of land ownership, all simply due to money savings (like in some regions of Balkan countries). In such conditions governmental awkwardness in taking steps to solve the issue, leads to extreme spatial inconsistency and related socio-economic problems that block appropriate development of the city. Policymakers has not yet found any relevant tool for dealing with consequences of that uncontrolled growth, as opposite, others have not yet found the cure for shrinking cities to heal their economy and depravation of urban structure and society.

In turn of XXI century Informal Settlements represent the most rapid urban development on most continents. It is visible mostly in Southern and Eastern Asia, South and Central America, Africa, and what is most wherein, even in Southern Europe and some places in North America. Although their formation lays on different backgrounds, the spatial complexity and disorder they represent is most often similar. Commonly known tools, used by designers in a planning process for these areas are certainly digitized, yet rarely parameterised, and even more rarely based on the changeable datasets assuring flexibility of delivered project.

INTRODUCTION

This research paper describes difficulties and opportunities of implementing real-time GIS data analysis into the process of developing large scale masterplan proposals, on the example of Northern Boulevard competition in Tirana, Albania. There were 6 international architectural and urban offices invited to participate in that contest. Author of this paper was a member of the design team on behalf of KCAP Architects and Planners from Rotterdam. The area of the site was a 1k ha zone of informal settlements in the northern part of the City of Tirana. That area was lacking of proper infrastructure, functionality and spatial organisation. Design teams were asked to integrate that urban structure into a coherent district, dissolved within an historic city fabric.

The whole area of northern Tirana is scattered by unrestricted housing initiative formulated on the quazi-ruffian basis. It includes wide spectrum of accommodation options, from high standard apartment blocks to semi-temporary squat shelters recalling slums. It begins at the south, close to the Tirana main railway station, near the city centre, it continues up north to Paskuqan Park, and it has a width of the whole East-West city borders. The area is split in a half by mountain stream coming longitudinally. The site has no consistent road structure and just basic media infrastructure.

Design process was divided into sections. Author of the article was solely developing the initial stage of the design process that included spatial and functional analysis, and design guidelines for further elaboration in the hierarchical process of design. First part took four weeks and it focused on geospatial interpretation of the analysed area. As a result of prepared work, the author established following methodology that might be implemented into the design process, to obtain desired outcome. It was not the result of the knowledge copyrighted by KCAP b.v. but only author's personal considerations made beyond office hours and developed on private software contributed to own research.

METHODS AND MATERIALS

The main focus of the research was on investigating methods of incorporating real-time open data sources into a design proposal for areas demanding flexibility in the post-delivery stage. As the research question stated, production of masterplans for ever growing illegal settlement require novel tools for the design stage and delivering finished concept. Thus, for that purpose, and referring to B. Meeda statement that "it is unlikely, however, that single program will be sufficient for a complex project", [10] the Rhinoceros 3D and Grasshopper were chosen as platforms merging widest range of plug-ins offering highly parameterised space modelling and analysing. Above all, the plug-ins establishing access to GIS data, were chosen. These were "Elk" and "Heron". Additionally the "Configurbanist" plug-in using Space Syntax algorithms was used to allow high standard spatial analysis of the plot.

Using that software the data from Open Street Map (OSM), containing geospatial information about the area, was linked into the program, creating changeable environment of variable parameters. This changeable environment was obtained due to the open source character of OSM that allows random users updating GIS information with no restrictions. From data provided, the information about the road network, land use, function of the buildings, water system, topography, public space etc. was crystallised and managed separately. Each component then, allowed analysing specific parameter of the area and establishing relevant design directives. These few basic parameters taken into consideration were to secure the flexibility of the design built upon.

The stage of analysis required, above all, certain knowledge of urban planning and professional experience to assure that proper parameters were included in the sensing algorithm. Yet, these skills are not to be evaluated in this research paper since its matter concerns only the aspect of analysis and the tool implementation and its impact on design process and results. [11] The process of producing the design was highlighted as a fundamental determinant of space creation. [12]

To prepare a rich background for further stages of the design process, few land parameters were elaborated and based on them the design principles were formulated (fig.1).

(1) Buildings height and density

From the data obtained through OSM, the distribution of buildings was read off. The algorithm took into account the size of the building outline, the distances between the buildings, the number of the buildings in the cluster and their heights. These information were analysed to find areas of too high and too modest gentrification (fig. 2). These areas were then highlighted as ones to be ordered properly by reconfigurations, removals, super-structuring and such; or the ones with the potential space for a fresh development. It was the very core analysis, drawing the distribution of possible urban interventions within the plot, allowing most sustainable integration with the respect toward existing settlements.

(2) Functional connections and exes

In a macro-scale context, the whole city of Tirana was analysed and few main functions of the land was interpret. Basing on the information about land ownership and land character, all parcels across the city were grouped by their location and sizes picturing the areas of the most vibrant activities. From the network of these areas the two main representatives, positioned within the study area, were selected and the spatial connection with a gradient amenities was highlighted as a possible merging solution. This step was taken to provide the outline of the possible program intended for the core of the site. It allows proper positioning of main features to make them correspond with the broader functionality of the city.

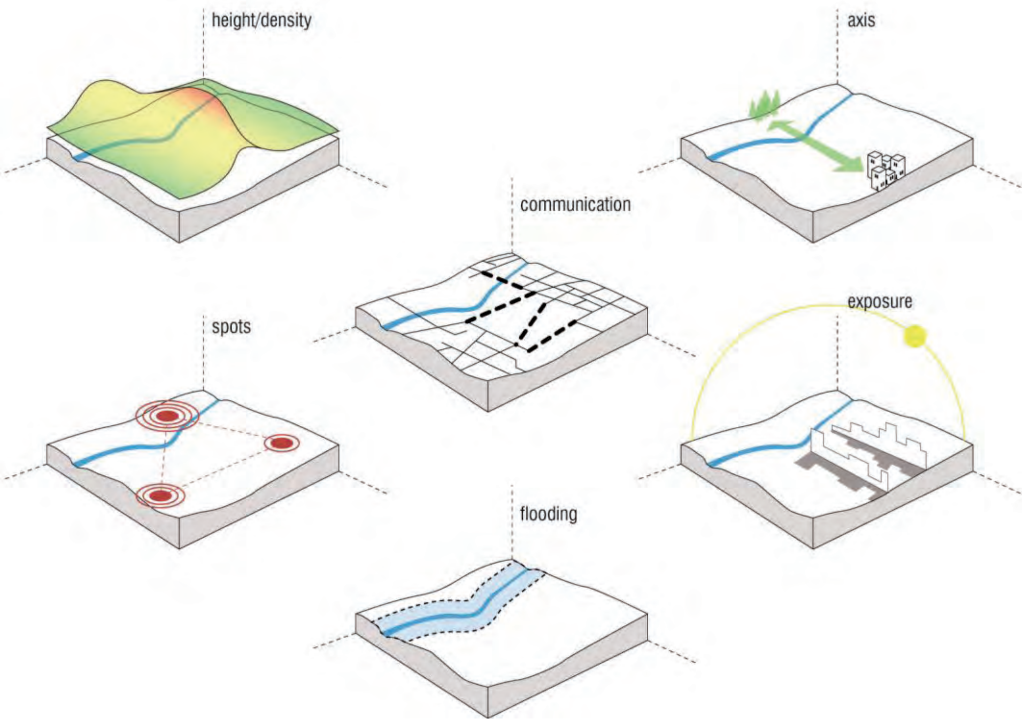

Fig. 1. The basic parameters of the plot.

(3) Communication

Another parameter was the road network. It was one of the most complex since it consisted of the streets hierarchy, public transportation and railroads. These three aspects were analysed separately and then merged into one coherent diagnosis. First of all the crossings and the stations were separated from the railroad structure to indicate possible functionality and importance of the neighbouring areas and street network arrangement. Secondly the highway system was interpret by zoning its surrounding gradually and marking highway exits as possible immense traffic directions. Thirdly, to obtain relevant information out of the datasets, the space syntax algorithms were used to check the spatial connectivity of the existing road structure. In this regard, no highways and railroads was taken into account, due to a walkability basis of the Space Syntax methods. The network was evaluated and all inconveniencies were graphically interpreted and marked. Also initial solutions that might solve observed issues, were proposed.

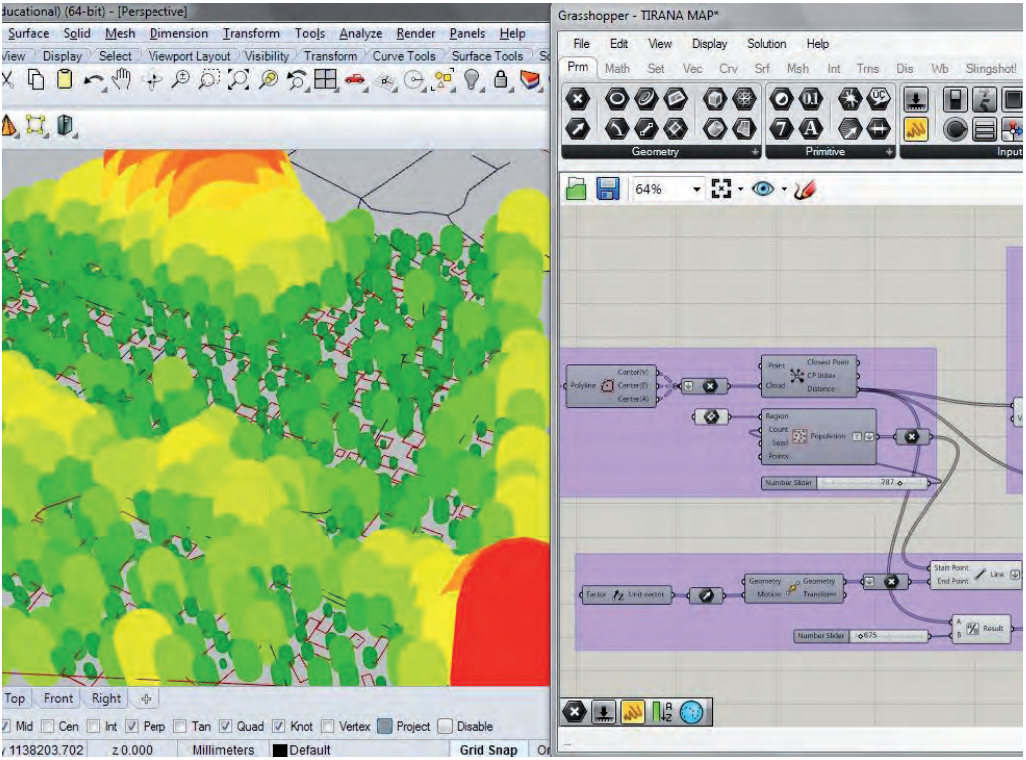

Fig. 2. Example of the Grasshopper algorithm (right)
and its graphical interpretation on the map (left).

(4) Cultural and commercial Spots

Assuming that certain types of the buildings gathered in a closest circumference cause the emergence of the local attractiveness of the area, the simple algorithm was produced that reads the functional tags from the datasets and establishes graphical interpretation of their locations. Through several attempts with changeable parameters, the map of spots illustrated the congestions suggesting places of wider interests. The pattern of their distribution was enriched with their mathematical continuation, suggesting new spots that may arise.

(5) Exposure and topography

Because many design principles should be formulated with respect to geographical conditions, the two most basic of them were considered in this experiment. These were: topography and sun exposure. The first one indicated areas of steep slopes and direction of isochrones that might influence road networks and building typologies. The second took into account orientation towards sun, the existing heights of the shading buildings and the topography as well. It helped visualising the areas of good lighting conditions and those that need decimating. These two were confronted and areas of best conditions were found and marked on the map of the site.

(6) Flooding and Water management

The specifics of the developed area required consistent methodology of dealing with the issue of flooding and managing water reservoirs altering in water presence. These two aspects were constant and predictive, thus the design directives were unchangeable and did not refer to the external database. In this respect they were not considered vital aspects of the experiments, yet still they influenced deeply the results of analysis and subsequently the process of designing.

RESULTS AND DISCUSSION

The process of developing proper scripts to obtain desired functionality, seem relatively straightforward. Plug-ins used for that purpose had enough predefined commands that simplified the management and production of the algorithms. Each parameter analysed in the experiment, had finally the potential to give necessary knowledge about the site. Nevertheless each of them was fairly abridged in order to be completed in the timeframe, and did not contained the whole complexity of thinking and analysing which is the case of human-based analysis.

Implementation of external GIS data into a preliminary stage of conceptualising the design proposal showed that it may automatize the process of any masterplan design. In the scope of the research few changes were made in the OSM database, and every time the outcome was simultaneously updated. The results from computer aided methodology based on parametrics were then compared with the results obtained through the regular urban man-made analysis done by using simple CAD software and pen drawings. This second approach was based only on the knowledge and experience of professional urban planners. The results were seemingly comparable, so it proved that the direction described in the research hypothesis is achievable. That properly developed algorithms may form the answer for the rapidly changing environment which needs coherent spatial guidelines. Nevertheless in the scope of the research only analysis were taken into account, promising that later stages can be implemented in the same manner, ending with a delivery of the fully parameterised design proposal.

The question and the issue that is still valid is the post-delivery usability of the parameterised urban plan. Current methods of passing the bills related to urban planning, that are applicable by municipality and policy makers, are dependent on material paper-based decisions. Although computerisation is spreading in a highly developed countries, it is rather rare in the countries struggling with the problem mentioned in the title of this research paper. Thus methods described above could mostly be understood as effective tools to increase velocity of the preliminary stages of urban planning, and only backcloths of deeper change in urban planning.

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