Teaching Landscape Architecture: An Experimental Approach Combining Data-driven Methods and Parametric Modelling

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Abstract: This paper aims to research a connection between architecture and landscape by way of a digital action between code and understanding the differences between top-down (architecture) and bottom-up tendencies (landscape). In close cooperation between landscape architects with a landscape ecology background and students of architecture, we tried to combine analytical and design tools. We have achieved interesting results using tools such as GIS, Rhinoceros and the coding platform Grasshopper. Our case study takes place in Brno, the second largest city in the Czech Republic, with one of the biggest urban renewal areas in the country.

Keywords: Parametric modelling, urban renewal, education, succession

1 Introduction

The fascination with the potential of the area connects architects and landscape architects at workshops and brings impetus to the public debate. For our teaching purposes, it is great enough to work with GIS data and use the results for the parametric modelling in Grasshopper. Landscape architecture in the Czech Republic traditionally has a strong tradition as regards landscape analysis and ecological planning. GIS as an analytical tool is seconding CAD and Sketchup in digital design tools. On the other hand, Rhinoceros and Grasshopper have not yet been applied to teaching (in the Czech Republic), although they represent a vital tool for landscape architects too (e. g. BELESKY 2018).

Architects tend to do more experiments in design. Combining both approaches in a series of student workshops, we examine the different approaches of the two professions. We have used the bottom-up approach to investigate the ecological structure of landscape in the way Koh Jusuck refers to it (KOH 2008), instead of using the obligatory top-down approach. We also use the bottom-up approach to investigate the phenomena such as flow, borders, intimacy, and suitability.

The Palimpsest stands for a landscape, heavily charged with traces and past readings (CORBOZ 1983), the word 'successional' is derived from ecological succession development of population in space and time (FORMAN & GODRON 1986).

The design principle follows landscape urbanism principles, which aim to create functionally and spatially interconnected systems of green areas and public spaces, providing support for the integration of blue and green infrastructure into cities. Landscape in the holistic sense, or an ecological concept becomes a model of how a city should work. Landscape urbanism does not deny the intensification of the urban structure or the functional use of green areas.

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2 Method

We used the layered bottom-up approach for the landscape analysis. For the intangible phenomena like flow, intimacy or borders we also use the bottom-up approach. This bottom-up approach starts with a great issue which is broken down into sub-issues, as if you made a design to solve a problem after having collected the parts to make that design.

Because we worked with a large amount of data (territorial variety and the area of the territory investigated), it was suitable to form a "magnifying glass" so as to focus on the territory investigated for the algorithm verification.

In short, the main design is divided into sub-designs. The bottom-top is the approach to a problem in which you first see what is available and you then find the solution based on these bottom elements.

The students tried to find an ideal structure of a new part of Brno by examining the key natural processes and using the genetic algorithm generated by parametric modelling.

2.1 Landscape Urbanism

Landscape urbanism represents a change in the perception of the importance of individual structural elements within an urbanized environment. It shows that it is more suitable to organize the city by designing an urban landscape, rather than designing individual buildings (WALDHEIM 2006).

Landscape urbanism was formed at a conference in Chicago, Illinois in 1997, in response to the continuous growth of cities, which went hand in hand with a careless expansion of construction in the 20th century. The name was formulated by Charles Waldheim, Professor of Landscape Architecture, Director of the Office for Urbanization at Harvard University Graduate School of Design. By combining the words landscape and urbanism, he wanted to point out the need for the reintroduction of the crucial link between the city and natural systems.

Just like Frederick Law Olmsted in the second half of the 19th century, who artfully inserted the element of ecology in landscape architecture, or Ian McHarg, who preached the need to design in accordance with natural processes in the 1970s and who then formulated his main ideas in *Design with Nature* [1], also Charles Waldheim searched for a solution to the existing situation in the processes of the landscape: landscape as a perfect bumper for various structures; landscape as an interconnecting media; landscape, adroitly defining the urban form. He legitimized the perception and understanding of the city through the optics of the landscape. "The landscape is not only a model for today's urbanism, but more importantly, it is a model for the process" (ALLEN in WALDHEIM 2016). The landscape thus becomes a clearly measurable phenomenon and a perfect knowledge of the primary landscape structures (geology, pedology, climate and hydrology, etc.) allows for determining where to build, where not to and why.

The main theses, which e. g. include the creation of functionally and spatially linked systems of green areas and public spaces, the creation of interaction networks of blue-green infrastructure, perfect knowledge of the primary landscape structure, the emphasis on diversity, variability and multifunctionality of the territory, and the emphasis on the maintenance and extension of vegetation elements, may seem obvious nowadays. What remains novel is the perception of landscape urbanism as a "final and at the same time open work". This indicates clearly defined mature spaces that can very quickly respond to changes (WALDHEIM 2016).

Additionally, it is unusual that he pays attention to primarily residual areas (Parc de la Trinitat in Barcelona, 1993, Enric Batlle and Joan Roig) or cultivation of brownfields (Fresh Kills Landfill, 2001-40, Field Operations). On the contrary, the perception of the landscape as a purely functional component, i. e. an element whose aesthetic quality is not important, may seem troublesome. Further troubles may be found in the deliberate blurring of the boundaries between urban and rural areas, which could lead to an unwanted homogenization of the landscape.

2.2 Parametric Modelling

At the end of the 1990s, the method of parametric modelling began to develop – a method in which digital technologies and software are used to create design. The software creates an algorithm based on input data or parameters and certain rules (e. g. true, false, if ... then ...) and generates possible forms of the design by defining variables. I. e., not one resulting form is defined, but rather a catalogue of options. Therefore, the way in which the form will be generated is designed, allowing direct response to the specifics of the place.

An inclination to the creative method of parametricism can be found in the work of deconstructivists of the 1990s, e. g. Zaha Hadid, Greg Lynn and the American architect Peter Eisenman, specifically in his innumerable diagrams. The basic idea of parametricism was formulated by Patrik Schumacher, who points to the use of natural construction principles in architecture and city planning. Currently, this design method is used increasingly, thanks to the development of computing technologies, specifically the sophisticated parametric techniques (e. g. Rhino + programming program e. g. GC), which allow an exact formulation and execution of complex correlations between elements as well as the adaptation to the socio-economic era of post-fordism. The basic idea of parametricism is thus autopoiesis and "continual differentiation" (SCHUMACHER 2008). It is an open dynamic process, which allows simulating changes. At any time during the design, it is possible to modify the script or the input parameters, and thus achieve an instant change in the design. A fundamental change in the architects' approach to parametricism was brought about by the launch of Grasshopper to the market, which provided common users with access to programming.

At the beginning of each process, it is necessary to establish a clear goal, which the author wants to achieve. Further, the basic parameters/elements and their mutual relations within the chosen site need to be defined. We know the inputs, but not the target appearance. The next step is the generation of computational geometry, defining variables, which may be based on natural principles. Finally, it is necessary to choose the optimization process, which uses evolutionary algorithms.

2.3 Inputs

Analytical GIS tools were used to analyse landscape layers such as hydrological features, soil and relief shapes. These characteristics served to determine the potential vegetation. In the case that potential vegetation coincided with the current developmental state of vegetation, these areas were the basic element, i. e. the areas that were evaluated as extremely suitable for the development of the succession stages and the core of the natural landscape, the future blue-green system (HILTRUD & PIERRE 2012).

Parametric modelling allows external influences (terrain, water, sunshine, etc.) to enter the design as parameters and adapt the design to external conditions – a perfect knowledge of the primary landscape structure is a necessity (REED in WALDHEIM 2016). Therefore, landscape features such as digital terrain model, soils, vegetation and hydrologic features were exported from GIS to CAD files for use in Rhino and Grasshopper.

3 Case Study

Brno is the second largest city in the Czech Republic, a university city with a strategy to promote research in the field of IT and Life Sciences. Brno is recognizable in the field of world architecture by its interwar period of functionalism (e. g. Ludwig Mies van der Rohe, Villa Tugendhat). Since the end of the Communist era, Brno has turned from the heavy and light industries towards the service industry.

The so-called Brno Triangle is one of the largest urban renewal areas in the Czech Republic, a space of railway properties, abandoned buildings and a mixture of floodplain forests. The master plan for the Brno Triangle has been searched for 100 years and is related to the relocation of the main railway station. The existing railway station, situated directly in the city centre, is supposed to be relocated 1km away, into the Brno Triangle. This massive relocation opens up a space for a development of a new city quarter ("Europoint Brno"). Even though the architectural competition has been completed, the final form is still an object of discussion, because the model area has a huge potential as a built-up area, a peri-urban park or a corridor connecting the city centre with the southern edge of the city. The existing designs want to build up the area of the present meadow; however, we consider the meadow valuable, so it is recommendable to leave it as a park and build the city where it has been unfinished.

The model area of the Triangle comprises 94 ha of brownfields, a railway junction and abandoned properties. The principle for the development was successional palimpsest, a connection between landscape strategy and architectural articulation. If nature tends to reach a climax, architecture should follow. The design principle was investigated during an intense 4-day workshop with students of architecture and landscape architecture in their 2nd to 6th year of study. 15 students were involved in the workshop out of whom 10 were architects and 5 landscape architects and there were 4 tutors. The field visit and analysis were prepared before the workshop, since the workshop focused on testing and developing the Grasshopper tools.

3.1 Topics

We operate in these domains: the borderline between built-up and undeveloped areas, flow, intimacy, and suitability.

The basic concept was based on the belief that the rarer the natural element in the place, e. g. if the plant community approaches the climax stage (final stage of succession, a stable unchanging community adapted to the locality), the more architecture should give way and vice versa. For this purpose, maps with data content (digital terrain model, soil, vegetation and hydrological subgrade) were imported into Rhino from GIS. Subsequently, thanks to these characteristics, the potential natural vegetation was determined. In the case that the potential natural vegetation resembled the current vegetation type, these areas were considered basic elements, i. e. areas assessed as highly suitable for the development of the landscape element of the design – the future blue-green infrastructure system.

Boundaries

Tool: Grasshopper + Rhino, plug-in Nudibranch, Game of life

The first motive examined was the search for the boundary, both physically and visually, to optimize the ratio of the built-up and undeveloped areas.

It is enclosed by railways, which create a significant barrier. In the case the railway was partially broken, for example, by underpasses, the situation would be new. The territory was perceived as a combination of two distinct urban structures: vegetation and built-up areas. Our view is that areas of the same species tend to connect and support each other, see fig. 1.

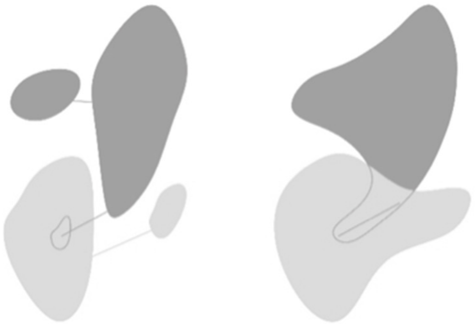

Fig. 1: The main principle. The areas of the same species tend to connect and support each other; the areas, which are too small and abandoned, perish. Darker colour represents the vegetation, lighter colour represents built up areas.

The areas that are too small and secluded cease to exist. Key areas were selected from the built-up and undeveloped areas (in our case, wet depressions in flood areas within the undeveloped area, and compact urban structure within the built-up area), and they were defined for the purposes of programming as attractors of different values.

Nudibranch

The denser the presence of small objects (city centre and centres of city districts with residential housing), the greater the potential for the structure's survival; by contrast, a loose development (e. g. production halls) tends to disappear. The elements with a potential for evolution were selected from the vegetation areas (determined by the correlation of elements of the primary landscape structure), for example, surroundings of waterways, wet depressions, forest stands, etc. Their centre was determined and the value of attractors within the area increased. The urban and vegetation structures thus literally compete for space in some places; however, this has transformed into their cooperation, for example, in the form of green roofs and green facades, etc.

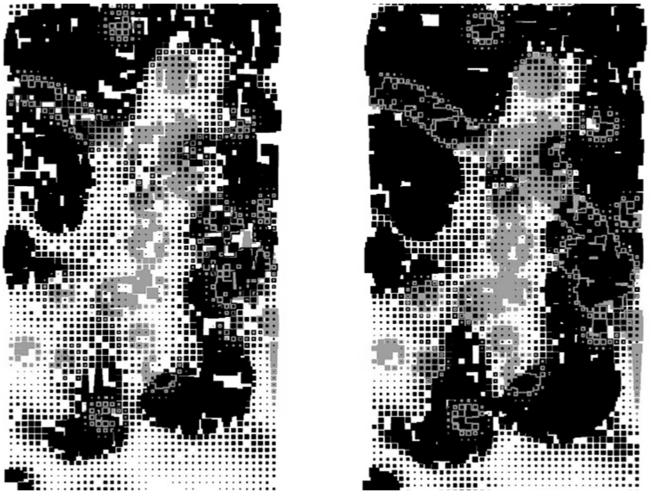

Fig. 2: Use of the **Nudibranch** plug-in which aims to automate the attractor development process. The lighter area indicates plant elements with the greatest potential of growth (determined by the correlation of elements of the primary landscape structure). Black colour shows the growth of the urban development.

Game of life

Using the algorithm based on "Life Games" by British mathematician John Conway, we simulated the growth of urban and vegetation structures. In territories divided into a regular grid we have identified important areas of urban structure and greenery with potential for development and subsequently applied simulation of growth. This modified "game of life" is based on the assumption that the places with a high-quality urban structure (with functional city-forming elements) have a higher probability that new buildings will emerge. The same is applied to the vegetation element. During the process, newly emerging structures were compared after a chosen number of iterations.

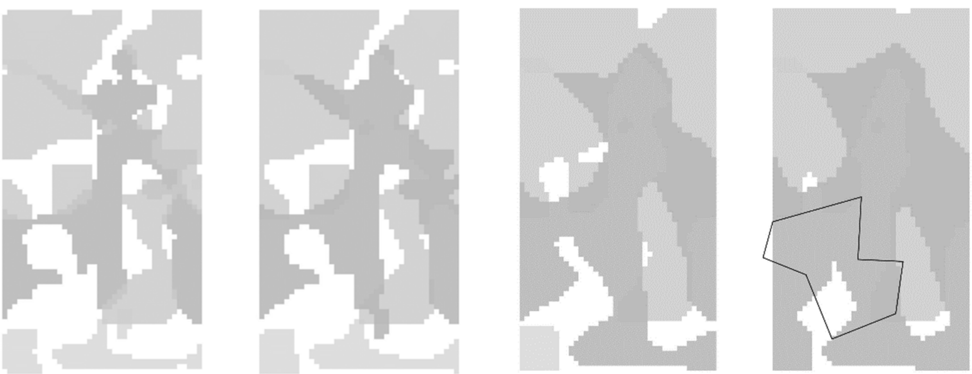

Fig. 3: Use of the **Game of life** plug-in. New structures have been compared after a certain amount of iterations.

The outcome is able to predict the development of valuable elements in the territory and, therefore, control the design so that the vegetation can gain a sufficient time to regenerate and then regenerate the place [2]. Darker colour represents the vegetation, lighter colour represents built up areas.

Flow

Tool: Grasshopper + Rhino, plug-in FlowLines (Streamlines), Anemone (Wooly Paths)

The theme of the flow responds to the human perception of space during movement. Humans perceive space differently when in a train or during a simple walk. The faster the movement, the less detail is seen and thus a larger space is necessary for a creation of a comprehensible structure.

The chosen algorithm FlowLines allows visualizing a vector field, generated by positive and negative points. The routes of lines are calculated using the "fourth order Runge-Kutta method" developed by German mathematicians, C. Runge and M.W. Kutta around 1900. The density of the lines represents the flow and determines the loading of these communications (streamlines). More density means faster flow. On the contrary, stops (points, attractors, such as traffic stops) slow down the flow. The Anemone (Wooly Paths) plug-in creates the ideal links between the routes with respect to the designated attractors of the place (entrances to the area, values of the area...). The algorithm ensures continuity of the generated links (straight lines).

Fig. 4: **Flow** – the most ideal connection of the paths based on the identified place attractors (entrances to the territory, land values etc.). (1) paths in the park, (2) broader relations, (3) the broadest relations.

Intimacy

Tool: Grasshopper + Rhino, plug-in Isovist, Galapagos

In this experiment the area of our interest was the intimacy of spaces, or their openness and enclosedness + subsequent localization in the given area. The idea of easy orientation in the space was developed by forming a visual access to existing or created landmarks. The existing as well as the newly designed paths in the park serve as attractors generating the park space. The original structure of the greenery and its density are also attractors that affect the location and size. We follow similar features where there is potential for a certain type of green space. And we will use the properties of this space as inputs to generating the development of the others. Isovist is a part of the Space syntax, which was developed in the late 1970s/early 1980s as a tool for the qualification interpretation of the space, specifically, a simulation of likely effects of its designs on their users. The uniqueness of the space syntax consists in the identification of the basic links within an area. Isovist creates an image of the entire area that can be seen from a particular point. The output is the formation of the greenery density throughout the territory. Based on our input parameters, open, semi-closed or enclosed public spaces for cultural, sporting and recreational events are generated. Based on the analysis, we have determined which types of activities need what space (yoga – enclosed, picnic – open). The boundary between spaces, and thus the openness and the enclosedness, is determined by the density of vegetation and the density is determined by its location with respect to the above-mentioned attractors.

Galapagos is an evolutionary algorithm. Its main advantage is that it is a highly transparent and clear process that allows a high degree of interaction with the user. As a drawback, it is very slow and does not guarantee a solution. In our case, Galapagos sought out ideal positions for trees in respect to the defined value of openness/enclosedness.

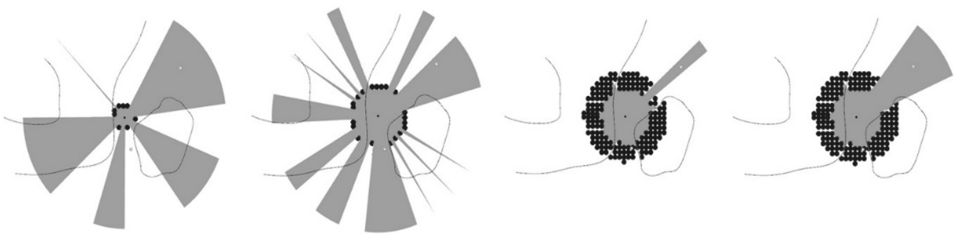

Fig. 5: Intimacy analysis output – the formation of the greenery density for different types of events

4 Conclusion and Outlook

The effort to suppress city expansion into the landscape leads to a continuous search for potential development areas within the built-up area. The awareness of the climate change impacts and the related negative phenomena, the increasing desire of inhabitants for a good environment, the increased interest in good architecture, as well as favourable economic conditions at the end of the 20th century formed a background for new, hybrid or precision theories that respond to the changed priorities within the planning of our living space.

Architecture and nature do not compete; their merger would bring a great advantage. Additionally, their designs require interdisciplinary cooperation, if the aim is the formation of viable cities.

It is essential to overcome the perception of the public space as a point of dispute between architecture and landscape architecture and realize the benefits this cooperation brings. During the experiment, the students proved that each of these fields has its own approach and way of seeing the city. Landscape architects can artfully look for natural values in the territory and they are capable of designing the blue and green infrastructure. On the contrary, urban planners better understand the forms and economy of city development, the relationship of the traffic structure with the development, etc. Looking into the history, e. g. at F. L. Olmsted's work, we can hardly define whether his work is an urban design or a landscape architect's creation. It is necessary to stop looking for boundaries between designing one and the other, and learn to integrate knowledge from various fields.

When used for landscape architecture, parametric modelling has proved to be useful, primarily at its analytical and simulation stages; correct code setting and its generation guarantee multiplicity and diversity of the design, its consistency and ability of the elements to influence each other over time. This principle can be observed within succession, for example – one entity affects the other, thus bringing an effect of synergy. There is no direct proportion within landscape.

Therefore, parametricism must be perceived as a tool fully dependent on the creator, i. e. the person who sets the parameters. The question remains whether this tool is redundant for a conscientious designer with a good knowledge of the context. The advantage of its usage is the fact that thanks to the complex correlations the software is able to calculate in a short time, it allows the designers quickly orientate themselves within a complex territory, make a catalogue of possible designs, and thus it actually provides the designer with more time for the design. It is necessary to be observant, abstract from and formulate the data correctly when parameterizing the task – not all phenomena are easily put in parameters and translated to mathematics. However, the behaviour of nature and architecture contains these options, so the next step would be to explore more advanced simulations with the involvement of current agendas, such as machine learning, AI, etc.

Acknowledgments

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Footnote text

[1] Among others, the terms that have become foundations of GIS systems are formed here.
[2] The ability of plant elements to regenerate the remains of the industrial era has been known from many instances. They are implementations, whose strategies allow the redevelopment of old industrial sites at lower costs and greater efficiency than when other industrial tools are used. They are called phytotechnologies.