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MARIA HELENOWSKA-PESCHKE*

PROGRAMMING GEOMETRY AS CREATIVE PLAY WITH ARCHITECTURAL FORM

PROGRAMOWANIE GEOMETRII JAKO TWÓRCZA ZABAWA FORMĄ ARCHITEKTONICZNĄ

A b s t r a c t

In the twenty-first century "programming" is a key word that opens up unprecedented opportunities for the design and materialization of geometrically complex architectural objects. From the digital designer's perspective programming geometry can be seen as creative play with form and a process of generation/exploration, as well as the possibility of applying computing power as a co-designer in the process of finding solutions for complicated architectural design tasks.

Keywords: algorithms for generating geometry, parametric modelling-algorithmic, genetic algorithms

S t r e s z c z e n i e

W XXI wieku słowem kluczem, który otwiera niespotykane dotąd możliwości projektowania i materializacji złożonych geometrycznie obiektów architektonicznych jest „programowanie". Celem artykułu jest pokazanie iż programowanie geometrii z perspektywy projektantki/ta cyfrowego może być postrzegane jako twórcza zabawa formą i/lub możliwość włączenia mocy obliczeniowej procesora jako współgrającego w procesie poszukiwania rozwiązań dla coraz to bardziej złożonych architektonicznych zadań projektowych.

Słowa kluczowe: algorytm generujący geometrię, modelowanie parametryczno-algorytmiczne, algorytmy genetyczne

* Ph.D. Arch. Maria Helenowska-Peschke, Department of Visual Arts, Faculty of Architecture, Gdańsk University of Technology.

1. Introduction

The process of searching for architectural form depends on an architect's individual style of work; however, an important role is always played by the means of recording a preliminary idea. As soon as designers discovered computer modelling capabilities for NURBS surfaces, animation and morphing[1], their interest in curvilinear geometry increased. "Playing with digital clay" was appealing – it gave greater freedom of language, stimulated creatively, opened up architecture to a world without domination of planes, and enabled virtual testing of innovative spaces. Visually attractive sculptural forms began to appear in competition entries and the architectural literature. They were often detached from utilitarian requirements and the realities of the building trade which resulted from the capabilities of software which was originally designed for the world of games and movies (e.g. 3DS Max, Maya). The task of translating virtual models into a workable structure fell on the shoulders of the constructors assisted by professional programmers. For some observers and architecture critics computer modelling was nothing more than a game for technology enthusiasts. The results of this were largely attributed to happy coincidence rather than a serious creative intellectual or design effort.

After 2009 when Explicit History made it possible to edit algorithms graphically, consequently programming geometry became available to people who did not have extensive computer knowledge (read: traditionally educated architects). It's successor, "Grasshopper", is currently very popular among innovative-minded students of architecture and professionals. With programming, architects not only gained the freedom to create, modify, optimize and analyse geometrically complex architectural objects, but also construct new design strategies based on mathematical, algorithmic notation of rules. The area of searching architectural ideas expands with new abstract concepts such as: emergence, the theory of deterministic chaos, self-organizing systems, cellular automata, L-systems etc.

The core of digital design is to focus attention on the generative process, rules and dynamic interdependencies instead of building a virtual representation of a previously determined rigid geometry. From this perspective, programming can be seen as instructive, creative play in geometry formation/generation that allows a wide range of variations within a design space to be examined. Programming can also be seen as an opportunity for CPU utilization as well as a co-player in the process of finding innovative solutions to complicated design problems.

2. Digital clay models

Programming geometry using Grasshopper leads to a parametric-algorithmic model/system that is a program which "includes the record of spatial relations, the rules for inheritance of features for sub-elements of the structure and the rules and principles for generating successive levels of hierarchical model." [2, p. 29] The search for shape begins with the development of design procedures in the form of a graphic diagram. This

[1] Special effects in motion pictures and animations that changes (or morphs) one image or shape into another through a seamless transition.

procedure is translated into a script and then run in Rhinoceros environment which results in geometric objects. The selection of key constraints/parameters – their number, role and location in the algorithm – will determine the range of variation within the same generative logic. By means of mathematical equations and parameters it is possible to build into a software controlled geometry demands that cover different aspects of design: such as its dimensions, structural rigidity, energy consumption, acoustic conditions, characteristics of building materials, and production.

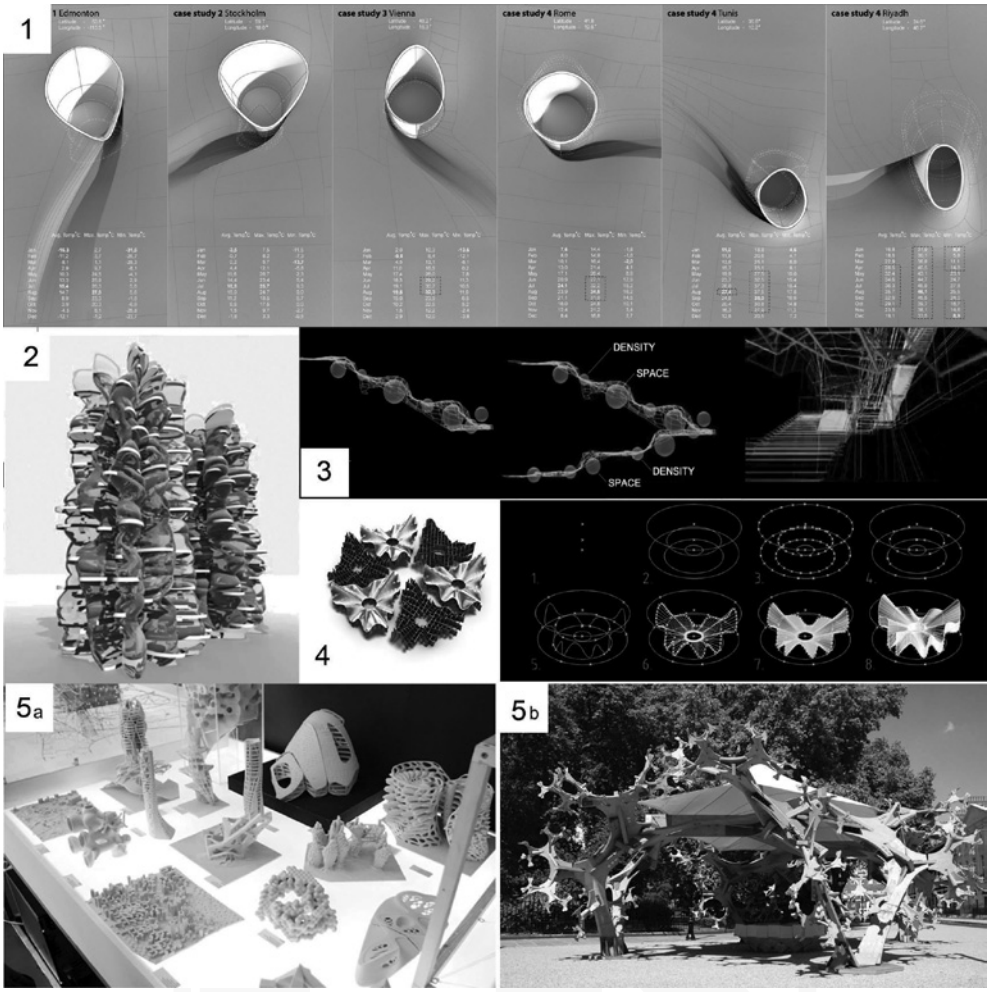
In return for the additional intellectual effort associated with the development of a scheme, the architect gains the opportunity to study numerous "what if" scenarios in real time. Due to the rerunning algorithm, it is possible to interact with the model by changing the values of the parameters determining its formal and efficiency characteristics. "Moulding digital clay" inevitably blurs the boundary between creative play and serious design effort. Driven by needs to meet the design requirements or pure human curiosity, testing every different design option provides design knowledge and shapes intuition. It also directs further exploration thanks to feedback in the form of geometrical instances and numerical analysis results.

The project Re-thinking Lascaux [6] is a fine example of how programming allows for new and innovative way of solving the weighty issue of energy consumption. Instead of focusing on applying the latest technology in the form of external mechanical systems, the designers from "moh-architecture" found the answer to the question of how space itself can help create an efficient sustainable solutions for a one family house. Precise, software controlled deformations of the house's form allowed the thermal efficiency of different climate zones to be optimized (Ill. 1).

Unfortunately the ease of playing with interactive geometry also results in the production of bizarre architectural propositions just because it is possible. Solving real architectural problems by means of programming geometry requires discovering and identifying the dependences in categories which used to stand outside the interests of the profession. The author shares the opinion that there is a need to broaden the architectural curriculum in architectural geometry programming and algorithms. "We don't let children drive or smoke or handle a firearm so why we are so eager to give to laymen the control over a powerful CAD package?" [4]

3. Toys to digitally explore forms

The digital designer community is involved in tools testing and development, sharing experiences and exchanging original scripts through a global non-profit network. Statements posted on parametric-algorithmic design and evolutionary forums show that programming geometry is usually accompanied by passion, satisfaction, and emotional commitment from the designer that is similar to the emotions experienced during play. Play is "one of the forms of human activity, voluntarily undertaken by an individual or a team, in which practical considerations, gathering and production of goods do not play any role, while the positive course of emotional experiences, and the sense of freedom of action and imagination are an indispensable prerequisite distinguishing it from work" [1]. This "positive course of emotional experience" is also revealed by the naming conventions for the software and interface graphics evoking associations with toys e.g. balloon, leaping kangaroo, origami. Starting from the already mentioned Grasshopper there is Kangaroo, Lunchbox, Galapagos, Weaver, Firefly.



Ill. 1. Re-thinking Lascaux design by moh architects, 2005
Ill. 2. Evolutionary study of residential building by Bakunowicz A, 2015
Ill. 3. Evolutionary design of Lidabashi subway station in Tokyo by Makoto Sei Watanabe, 2000
Ill. 4. Study of form by Students' Research Circle for Parametric Design WA PG, 2013
Ill. 5a. Students' projects, Ill. 5b. summer pavilion, Architectural Association School of Architecture, 2009

These applications are used to perform serious calculations and tasks. For example, Kangaroo is a physics engine for interactive simulation, optimization and exploration of form, Karamba is used for parametric engineering analysis of spatial trusses and frames, Galapagos lets you search for formal solutions based on evolutionary algorithms. The author's own experience shows that simply getting to know the possibility of new tools is addictive and educational fun with both processes and forms.

4. Form exploration and the "Game of Life"

Design activity is sometimes referred to as a team game in which designer, engineers, installers, investor, and a group of future users participate. Programming of geometry could in turn (under certain conditions discussed further) be seen as an experimental, conceptual game between two participants, namely the designer – a human being and a machine – the computer. In this game, the design space becomes a terrain of struggle in which a large amount of rapidly processed information/data gives a creative advantage over teammates. The computing power, which exorbitantly exceeds the computational capabilities of the human mind, can be used to generate solutions that go beyond the realm of complexity accessible to the designer. In practice it means the possibility of expanding the design space with abstract mathematical concepts such as chaos theory, fractals, random functions etc. "Concepts such as: randomness, infinity, limits, infinitesimal and even more complicated, such as complexity, emergence and recursion are incomprehensible to man not because they are metaphysical, mystical or magical, but because they rely on intellectual resources that are external and alien to the human mind" [5].

Generative procedures based on open algorithms seem particularly attractive to innovative designers. Open algorithms are those in which the solution to the problem is not predefined but is sought and found during the process e.g. as a result of the optimization mechanisms taken from nature (adaptation, selection, inheritance, self-organization etc.)[2]. This is due to the built-in algorithm internal generative feedback loop through which the program uses its own results as data input. A good example is designers' attempts to utilize cellular automata[3], a mechanism popularized by the "Game of Life". Invented by John Conway, the "Game of Life" was initially treated as a game, but aroused the interest of scientists in the field of physical simulators. Currently through the mechanism of cellular automation designers are trying to "grow" complex urban structures in accordance with definite rules (arising from the requirements and limitations of the program, context, etc.) (Ill. 2). Input arrangements and principles are specified by the designer, but the indirect results, and therefore the final outcome are not subject to full control (although they fall within the range of a predetermined generative logic). Data/information can be fed to the program directly by the user or by means of environmental sensors, which emphasizes the form's ability to spontaneously "take shape" and adapt. An example of the use of evolutionary computation methods in a real life project is the Oedo-Lidabashi subway line extension (Tokyo) by Makoto Sei Watanabe [7]. In the design phase, the network of underground corridors was created via a spontaneously evolving structure. (Ill. 3)

At the present level of knowledge, evolutionary computation methods are of limited usefulness in generating geometry because of the difficulty of resolving issues of internal cohesion of form and its meaning as an architectural object. Elements of structures obtained by these techniques can normally be materialised only by 3D printing, due to the complexity and irregular surface curvature. (Ill. 3)

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[2] Such procedures are appropriate for evolutionary design. J.H. Frazer pioneered this area of research in the field of architecture.

[3] The "game" is a zero-player game, meaning that its evolution is determined by its initial state, requiring no further input. One interacts with the Game of Life by creating an initial configuration and observing how it evolves or, for advanced players, by creating patterns with particular properties.

5. Conclusions

Operating in innovative computational design workshop remains the domain of an elite group of designers, which is due to the fact that programming skills have been considered until recently to be completely unrelated to the practice of architecture. The interest of the younger generation of architects and students of architecture in Poland provides evidence that the role of computers in the search for architectural form in the future will also increase in Polish architectural studios. (Ill. 4, 5a,b) This perspective opens up the possibility of transforming "the computational power of computers" in the "power of creative exploration." "The development of computational methodology intends to transform the role of the architect from the "originator of forms" to the controller of generative processes (design tool designer) in which the final product is not the result of human imagination but the generative capacity of specific processes." [2, p. 179] Computers introduce elements of a game, surprise and contrariness into the exploration of forms.

Psychologists maintain that the boundary between education and play or work and play is often difficult to determine. In the author's opinion geometric programming is intellectual work, which has elements of joyous fun – it inspires and liberates the imagination. Apparently, during the game, we tend to take a step into the unknown, we realize the illusory wishes which otherwise cannot be realized in the real world. Programming geometry allows interactive exploration of a form in virtual reality, which allows the realization of creative visions and concepts that may now represent a "pure dream" but which may materialize in the future. "This game full of charm requires not naive amateurs practising it only in free evenings, but someone who has completely assimilated its sizable part and who demands full devotion and completely draws in its service." [3]

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