

# Modern technologies of architectural and urban planning modeling in design and training

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**Abstract.** The article shows the relevance of the use of architectural and urban planning, including parametric modeling, as a creative approach not only to the design of the urban environment, but also to the training of future urban planners. Compositional methods of plastic modeling are considered that help to combine the research process and the creative search process, as well as the logic and stages of working with parametric tools. Examples of constructing a parametric object algorithm using modern software are presented.

## 1. Introduction

The importance of using the modeling method in the modern areas of urban planning, architecture and design, as well as in the education of future urban planners and research architects is difficult to overestimate. It makes it possible to methodically and competently motivate to build the design process, while solving a whole range of tasks, the consideration of which is necessary in architectural science and practice, conceptual design and training. Architects and designers need to be informed about the tools that can facilitate their work, save them time and money. To show that for any type of modeling, source data plus some vision of the results is needed.

## 2. Materials and methods

Among the methods that lie "on the surface" of architectural and urban development, the following can be distinguished [1]:

### 1. Abstraction

The wealth of ideas about reality, the wealth of sensations associated with reality, can not be expressed in forms that are themselves taken from reality. Architects have always felt the inevitability of its new analysis and new synthesis and came to embody reality with new constructive equivalents that still retain contact with the similarity of form, but represent it in other materials and with a certain degree of abstraction.

2. *The concept* allows combining the process of creativity and the process of its research. The concept helps to identify the main idea, form the concept of a future urban development object without subjective emotions and tastes, and explore the conditions of its social significance, functioning and



aesthetic perception. In the concept, not only space and volumes are modeled, but also the features of their perception, their spatial adaptation in the city.

3. *Scenario* modeling is a very specific programming of a given “coloring” of perception of urban space as a scenario space. Scenario modeling helps to create emotionally colored architectural and urban spaces while maintaining sustainable signs of the chosen place.

4. *Identification* of the structure and variability in the modeling of urban objects.

Modeling of architectural objects in the form of computer models allows creating various variable spaces based on one model. At the same time, variability is created using various forms, colors, textures, materials and other well-defined means. Spaces created using the same model can be modified under the influence of various conditions. Spaces modeled on a modular grid have greater flexibility and variability. At the heart of any modeling of space is composition. The composition or aesthetic structure of space is formed according to the principle of coordination of parts in the interests of the whole. All compositions are built in space and in time and develop in motion. A movement, or system of connections, is the basis of composition. When modeling, there are several fundamentally different types of space organization:

- a self-contained classical composition, characterized by closed borders, hierarchical division of spaces, a clear direction of movement within the space;
- open flexible composition of space, the development of which is oriented towards the external environment. The composition is characterized by open borders, the absence of a spatial hierarchy and develops based on the grouping of elements of the same type;
- open universal composition of space without hierarchy, built on the principle of universal movement and repetition of the organization of a system of rectangular flowing spaces;
- Suprematist artistic composition, built on a free experimental arrangement of simple geometric shapes and volumes.

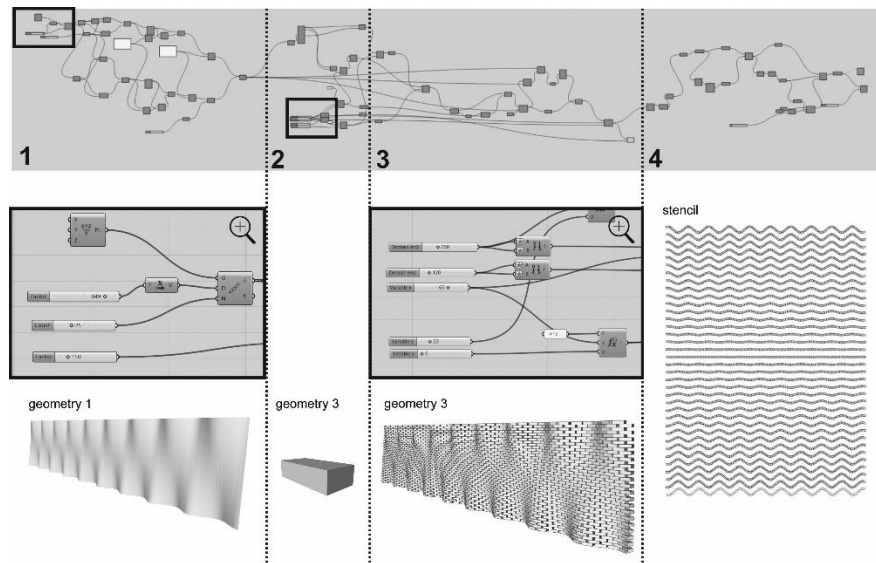
The presence of many computer programs for modeling architectural forms greatly facilitates the solution of a particular problem. Creative models created by students open up great opportunities for search engine design, for creating bold unexpected architectural forms. Today, computer technology has become an integral part of the life of almost every person. Therefore, design and architecture are already inconceivable without advanced computer-aided design tools. With the advent of parametric programs in modern architecture and environmental design, a new way of thinking, a different vision of the world arose, and ideas about geometry itself changed [2]. Parametric modeling allows creating a mathematical model of objects with parameters, in which some elements of the construction can depend on others, that is, when changing one of the elements of the model, all elements depending on it are rebuilt in accordance with the specified parameters. This significantly distinguishes parametric modeling from conventional two-dimensional drawing or three-dimensional modeling.

Now, among the leading architectural and design studios in the world, algorithmic-parametric tools - Grasshopper 3D and Dynamo [2] are gaining more and more popularity. They gave designers new opportunities for modeling the architectural environment, simplified complex mathematical calculations and allowed robotizing many production processes.

Creating a parametric object using modern software is carried out by constructing a "script", which displays all the elements used and the operations performed in the order they were created. In this case, the initial three-dimensional geometry can be performed in any 3D editors (Rhinoceros, Revit, 3DsMax, Maya, Solid, ArchiCAD, Autocad, etc.). Then the geometry is imported into the Rhinoceros3D software package [2]. An architect or designer (student), using the Grasshopper 3D graphics algorithm editor integrated with Rhinoceros 3D modeling tools, assigns parametric relationships and constraints to the geometry in the form of a system of equations defining dependencies between parameters. Algorithms mean a sequence of actions aimed at performing certain operations. Changing the numerical parameters in the constructed script allows you quickly calculating many different options for the model and choosing the most vivid artistic image of the final object [3]. If necessary, it is possible to set the layout of the elements of the finished object for further automated production or print on a 3D printer as a layout for presentation and visual analysis.

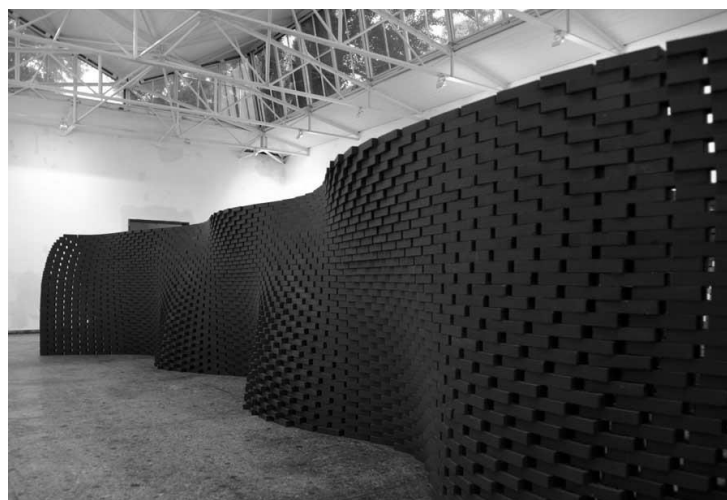
The architectural bureau Gramazio & Kohler has been using computer algorithms in its projects for more than 15 years and uses various types of robots to assemble them, they develop architecture not only through drawing, but also through the formation of spatial relationships using the potential of digital production computer technologies in addition to traditional design, engineering and construction methods.

Let us consider the stages of one of the possible options for writing the algorithm of the “negotiation wall” project (Figure 1, Figure 2) from the Gramazio & Kohler architectural bureau in the Swiss pavilion at the 11th architectural biennale using the Rhinoceros (Grasshopper) program.



**Figure 1.** Steps for writing a parametric brick wall script by Arseny Ivanov

At the first stage, geometry 1 (curved surface) is created, which will serve as the "basis" for creating the shape of the final object. At the second stage, geometry 2 is formed (in the project it is a brick). At the same time, digital sliders that are adjustable at any stage appear, which are responsible for the parameters of geometry 1, geometry 2 and, as a result, the size and proportion of the final three-dimensional object. The third stage of the script combines both geometries (1 and 2) into a single three-dimensional object (geometry 3).

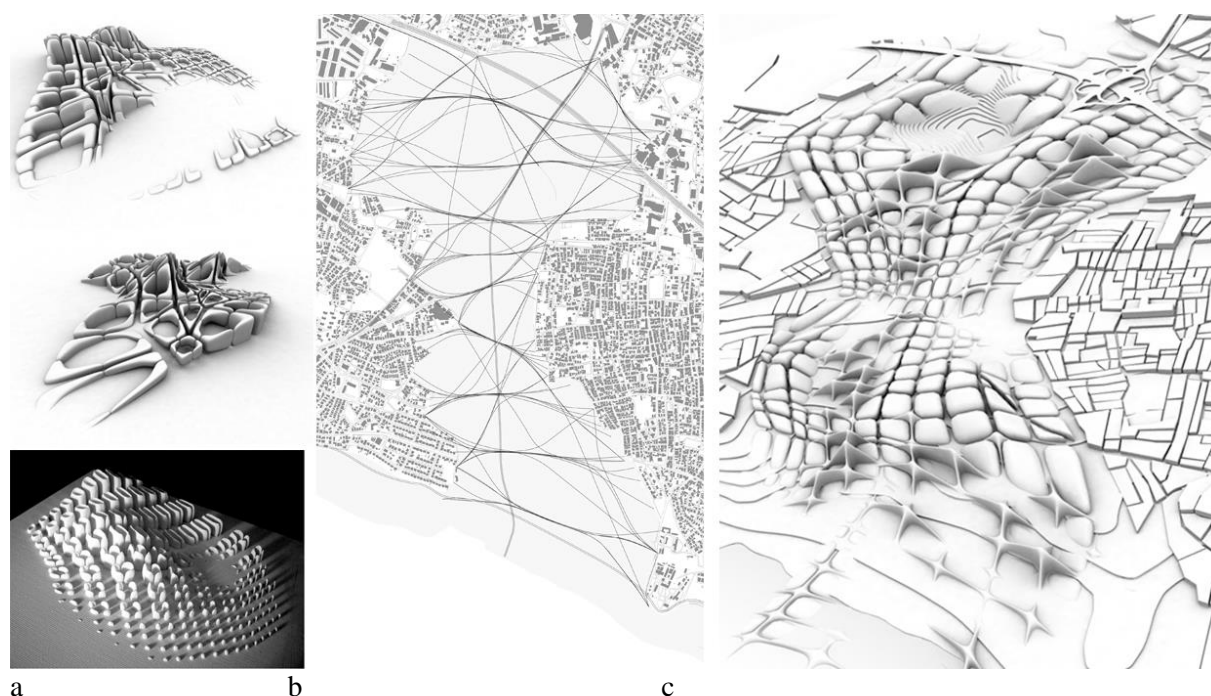


**Figure 2.** “Wall of negotiations” from the architectural bureau Gramazio & Kohler in the Swiss pavilion at the 11th architectural biennale in Italy. (Photo by Alessandra Bello).

AADRL Design and Research Laboratory proposed a new approach to the formation of urban space - "parametric urbanism", based on complex, smooth, seamlessly transitioning into each other spaces, developed using modern computer programs.

Architectural Studio ZHA has repeatedly participated in international competitions in urban space planning based on the principles of parametric urbanism, including: Soho City in Beijing (China), master plan Bilbao (Spain), business park in Singapore, master plan KartalPendik in Istanbul ( Turkey), Rublevo-Arkhangelskymicry district in Moscow (Russia) together with TPO PrideArchitects. These projects reflect the main aspects of the concept of "Parametric urbanism" proposed by Patrick Schumacher and his colleagues. [4]

The most interesting from the perspective of training urban planners is the example of designing the Kartal-Pendik master plan in Turkey, where the task is to create a new modern city center in Istanbul on the territory where industrial enterprises were located earlier.



**Figure 3.** Kartal-Pendik master plan, Istanbul, Turkey, (ZahaHadid, Architects).

a- Example of fabric: variant of a broken quarter, b- Hybrid bypass network and interchange network with the location of city streets and urban fabric, c - Global model.

Using the Maya hair-dynamic tool, a composite grid was created based on the future road network. In parallel, the architects of the ZHA studio worked on two main types of objects - towers and blocks, each of which was conceived as a "genotype", which could easily be further modified into a wide range of phenotypic variations. A parametric relationship has been established between the height of the blocks and the area of the plot — when the plots become smaller, the blocks become taller. Also, the shape of the blocks depends on the location of the network of paths and can be divided into several parts. [5, 6]

Due to the active development of modern computer technologies, today it has become possible to adopt the totality of external and internal characteristics of the main object (genotype) and apply this data (phenotype) to new objects, leaving the possibility of their individual transformation and development. Thus, a general feeling of creating a single "organism" is achieved; a three-dimensional prototype of the urban environment is created that is sensitive to changes in even one of the

parameters. In addition to the local dependence of the height on the size of the plot, a parametric dependence of the regulation of the height of the objects in relation to the perimeter of the entire territory is established. Thus, the high-altitude rhythm of urban objects visually indicates the rhythm of expansion and contraction of urban spaces.

Today, many different applications enable architects in a short time to model a huge number of options for the formation of urban development. For example, Galapagos has been developed for Grasshopper, which is capable of providing a universal platform for applying evolutionary algorithms. Models can define variables that are called genes in evolutionary computing. As the gene changes, the type and position of the model changes, that is, a mutation and adaptation to the existing situation occurs. Suppose that there is an object or a series of objects for which it is necessary to find the most favorable location in space relative to the development zone and the height of existing objects. The Galapagos application allows generating billions of unique rotations, which leads to various combinations of the shape of objects and their location in the environment. This allows a designer in a limited time to choose the best option. Another similar application for Grasshopper is Octopus, developed at the University Of Applied Arts Of Vienna in collaboration with Bollinger + Grohmann engineers. It allows searching for many goals at the same time, choosing your preferred solutions and making changes during the search, giving a variety of solutions. [7]

Other applications Ladybag and Honeybee, developed by MostaphaSadeghipourRoudasri for Grasshopper, give architects the opportunity to create a project taking into account the environmental performance of the projected area. Ladybag app imports standard EnergyPlus weather files (.EPW) into Grasshopper and allows creating interacting 3-D graphs (Sun-path, Wind rose, radiation roses, radiation analysis, shadow studies), providing almost instant feedback on project changes. Honeybee is used to simulate daylight and connects Grasshopper with EnergyPlus, Daysim, and Open Studio. Suppose that the sun will act as an attractor in the project, then the program will arrange objects (rotate, change shape, etc.) based on the calculation of environmental indicators in the given coordinates of the area. [8.9]

### **3. Results**

This example shows that, along with the well-known methods of compositional modeling, the use of parametric modeling for architectural and urban planning allows current and future urban planners to be relevant, meet new trends, and increase their labor productivity. [9] Competent modeling will allow efficient use of resources in production, get away from stereotyping, become a conductor of new technologies in society, stimulate social progress and bring up educational and educational functions. The architecture and design of the 21st century are subject to completely new laws of perception and modeling. Advanced parametric software programs are one of the effective ways to study and design complex systems, since they make it possible to use computational experiments at the level of building a computer model, determine the strengths and weaknesses of an object at the design stage, and quickly make corrections without resorting to unnecessary costs.

### **4. Discussion**

The growing popularity of parametric programs is based on a variety of functional applicability, ease of modeling complex forms, robotic production processes, the possibility of import-export of various formats, compatibility with well-known software packages for BIM-design. Changing the geometric parameters of model elements and the relationships between these parameters allows architects and designers applying various design schemes in a short period and avoid many miscalculations and errors.

### **5. Conclusion**

In real and educational design of complex urban systems, designers and urban planners need to study in depth the possibilities of modeling, including parametric design. This will allow current and future architects being competitive and sought-after specialists anywhere in the world!

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