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PHILOSOPHY OF PARAMETRIC DESIGN IN INTERACTIVE ARCHITECTURE FRAMEWORK

ФИЛОСОФИЯ ПАРАМЕТРИЧЕСКОГО ДИЗАЙНА В РАМКАХ ИНТЕРАКТИВНОЙ АРХИТЕКТУРЫ

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Abstract. This article describes the parametric design as a new trend not only in the design of technology but as a new approach to development philosophy of architectural elements from the point of view of interactive design. With the entry into the era of modern information technology available to architects, new design tools to create unique objects and to minimize the effort and time that the task, the process from design to determine the behavior and characteristics of the existing buildings has become completely digital. In parametric design and definition of the variables that affect the parameter changes, there are some algorithms of interaction and mutual influences that determine the shape, size, orientation, and other parameters of the architectural object.

Аннотация. Статья описывает параметрический дизайн, как новую тенденцию не только в технологии проектирования, но и как новый подход к философии разработки архитектурных элементов с точки зрения интерактивного дизайна. Благодаря вступлению в эру информационных технологий современным архитекторам доступны новые инструменты проектирования, позволяющие создавать уникальные объекты и минимизировать усилия и время выполнения задач, процесс от проектирования до определения поведения и характеристик уже построенного здания стал полностью цифровым. В параметрическом дизайне и определении переменных, оказывающих влияние на изменения параметров, существуют определенные алгоритмы взаимодействия и взаимного влияния, которые определяют форму, размеры, ориентацию и другие параметры архитектурного объекта. Использование инструментов параметрического дизайна является ключевым не только на этапе проектирования, оно также является фактором, влияющим на продолжительность жизненного цикла здания, его эффективность и удобство его эксплуатации конечными потребителями. Освещаются особенности параметрического дизайна, инструменты для его применения, примеры из архитектурной практики, а также рассмотрено его внедрение в разных масштабах архитектурной среды. В качестве одного из самых ярких прецедентов использования параметрического дизайна в архитектуре приведено здание Музея Гуггенхама архитектора Фрэнка Гери и описано программное обеспечение, использованное для создания его уникальных форм. Статья рассказывает о многочисленных способах и сферах применения параметрического дизайна в современной архитектурной практике в разных масштабах: от проектирования отдельных элементов интерьера, оболочки или фасада здания, разработки конструкций, управления и эксплуатации, до использования его в градостроительстве и планирования урбанистических элементов.

Keywords: parametric design, interactive architecture, philosophy, computer–aided design and new technologies.

Ключевые слова: параметрический дизайн, интерактивная архитектура, философия, автоматизированное проектирование, новые технологии.

By its' nature interactive architecture acts as a medium between the demand of users/society and the conditions of the environment. These factors constantly change over time. Traditional buildings are frozen in their static state, they are designed to satisfy only a limited number of predictable requirements, while interactive architecture is able to react to changing conditions and needs. The development of modern architecture within the parametric design methods field shows remarkable speed in progress. The past 15 years were especially significant and the application of parametric tools was very fruitful.

Interactive architecture is based on the actions. Actions take place in the environment all the time, they create it and define it as such. Performance evaluation system is required for design and post–design analysis. A number of methods of approach to the analysis of activities has developed in engineering and psychological research. One of them is focused on the selection of activities and operations in the "activity stream", on recognition of relationship and mutual transitions between them. Within this method the so-called algorithmic methods, methods of structural and statistical analysis are often used for description of actions. These methods make it possible to approach the assessment of psychological tension and the degree of diversity (or monotony) of workflow and operations. The second approach is described from the point of view of the requirements that are imposed to perception during the activity, attention, memory, thinking, etc. [1].

Industrial revolution made a dramatic impact on the field of architecture all over the world, modules were in fashion. But the modules were not effective enough, they didn't use all the advantages of the space, they were limited by mass production size constraints, not very adaptable, intending to provide a fast, budget conscious way of housing people. A new type of space, freed from this rigidity, fluid and unique evolved from it later. Antonio Gaudi, who brought organic concept to his architecture, being conscious of sunlight penetration into his buildings, may be considered as a very first precursor to this innovation. Certainly he did not create parametric buildings, this it started being possible only after the appearance of computer aided design (CAD) on the architectural scene.

Nowadays, many leading designers who engaged in parametric design over the past ten to fifteen years would to some extent agree with the fact that parametric design is not able to solve all the issues that the architect or planner has to face in his work. Moving away from the delimiting input techniques used to derive building forms and urban topologies, the design vanguard has begun focusing more on affective qualities of architecture design and its practice. Nevertheless parametric design is able to provide fast and effective solutions for problems that would take a lot of time for the architect or designer to solve with conventional techniques, turning complex issues into rational, simple decisions.

Grasshopper plug-in for Rhinoceros is the most typical software, along with SoftPlan, Chief Architect, Autodesk's Revit. Grasshopper is based on a number of scripts that implements the design process within parametric modeler coupled with Excel.

Parametric software allows to create elements and spaces in a way that would be otherwise impossible to calculate. Parameters set by an architect/designer/ determine the pattern of the final project. By controlling the shape, it allows architecture to react to context, environment and natural conditions, enabling a completely digital workflow from design to manufacturing. Architecture is not constrained by straight lines and basic cubic shapes anymore, now it is able to fit spaces, to be responsive to environment and its' conditions. Invention of computer numerical control machines (CNCs), that allows to custom cut specified unique constructive element one by one, started a revolution in architecture. *Frank O. Gehry & Partners* were the first to implement parametric

design methods in their work. After winning a competition with a curvilinear model of *Guggenheim Museum* **(**Figure 1**)**, they started looking for tools to realize this design. It required strong load bearing structures to sustain complex massive facades. Understanding that commonly used architectural software was not sufficient enough, they turned to *CATIA* software, used generally to design airplanes and automotive industry. Using such an unusual yet powerful tool lead to huge success, it allowed to finish the project before the deadline, spending less money less money estimated.

Behavior is the basis for the processes that takes place in real time. Swarm checkpoints in the process of forming relationship with each other are the main components of each building construction. These basic particles represent the players in the game. Players can be people, cars, construction sites, buildings, office space, parking lots, streets. They all behave according to a simple set of rules. Their behavior is an open system, which means that if one player has changed the behavior the others respond to the new parameters. The only thing remaining to calculate after the installation is the way user perceives the structure and how he acts. Therefore the process essentially is not the modeling of reality, but it is the definition of rules of the game forming the reality within the design process [2].

Figure 1: Guggenheim Museum — Frank O. Gehry & Partners.

Apart from the points/nodes there are also intensities/attractors that affect the space like electromagnetic or gravitation fields. The program of the design allows to adjust the degrees of freedom inherent in these fields and expressed in a variety of modes. For instance attractors allow you to work with an array of point/nodes, assigning them localized action. Properties of individual points and attractors, as well as the separated groups, are transferred to the parametric system, where each individual property is imposed to changeable parameter. Parameters can be either independent or dependent on other parameters, making a hierarchical complex system.

Finally, architecture started to be based on it’s changing performance in time, it’s no more only simulation within isolated sectors of design process, it is a space–time experience [3]. By playing with these variables (number of housing units along the street grid, specific distances from road/canal for single family, multi–unit apartment and high–rise apartment), the desired density of single family homes along the canals and the density of the apartment blocks on the hills can be designed.

The main aim of using parametric design in buildings’ construction is to improve their sustainability. and achieve a longer and more efficient life cycle. During their life period and construction buildings consume energy and make polluting impact on the environment. Negative aspects cam be reduced in order to increase the value of the building and improve its' performance. The most promising feature of parametric design is the variety of ways to implement it, it is a

technology that can be used in interactive architecture especially. It's implementation improves the performance and makes behavior of the building much more efficient in response to changing conditions of the surrounding. Interactive design is targeted on adjusting its' shape, the geometrical parameters vary, forming the buildings' behavior. The computational power of parametric design is able to ensure the most effective life of the building, the most appropriate response to the surrounding.

Parametric modeling and other optimization tools are aimed to support interactive architecture in its' complexity. This complexity depends on general types of aspects, to be considered as the variables of parametric design. First type is represented by human needs that refer to perception of complex factors, these needs must be decomposed in order to be understood and interpreted by the building and responded correctly. Other type of aspects influencing the building' behavior relates to the environmental conditions and surrounding built environment. The reactions of the building depends heavily on the input data that describes the context components and the way they change. Climate conditions, special local features, daylight affect thermal performance of the building. Both in short and long term of the building use users' needs and demands change. At the same time, environmental factors change as well, influencing the building performance. Its' functionality is affected by the number of inhabitants and solar radiation, wind velocity other factors. These aspect result in a situation with different levels of variables, that need to be considered in design process.

Wide possibilities of parametric design can be also expressed as systematic generation of a set of alternative design solutions based on preset range of independent parameters (Figure 2). A proper selections of the parameters and a correctly carried out hierarchy of geometric associations are the key points for definition of the resulting spaces and efficient performance of the building. In comparison with static architecture, there is a new approach to alternative design solutions represented by parametric models — they are not alternative anymore, but different modes of the same building, since it is able to change its' shape.

However there are some additional tasks when dealing with parametric approach, like necessity to identify respectively the proper geometric means of interaction, appropriate configurations of the predefined geometric properties, and suitable systems for adaptation. In other words the first aspect means that there is a need to identify the changes in various geometric properties that make a positive influence on architecture' performance during changes of variable conditions. It implies the analysis of geometrical variations with different behavior, sometimes beneficial or not that much. It is not an easy task to specify the mist important set of variable geometric properties of a complex structure considering multiple factors influencing it. The second aspect refers to identification of exact configuration needed to obtained the desired building performance, when the nature of changes in geometry is already understood. Rhythm of desired reconfigurations along with emerged pattern may be tracked during the building life cycle. The last aspect deals with identification of technical means integrated in the building (embedded computation and kinetic elements, mobile units).

Talking about parametric pendency referring to geometrical properties as a tool of interactive architecture, it is assumed that the changes of these properties are considered as a part of design. It is essential to identify the positive changes of the geometry in order to choose those variables that improve the performance within the changing environmental conditions. The result of performance evaluation under different variables is eventual dividing the variables into two categories: those that will be included into final design as the parameters, that describe the properties that will shape the space, and others, that describe static properties. In the end of this process the design solutions are reduced to a defined set of variables and constant properties of the geometrical form.

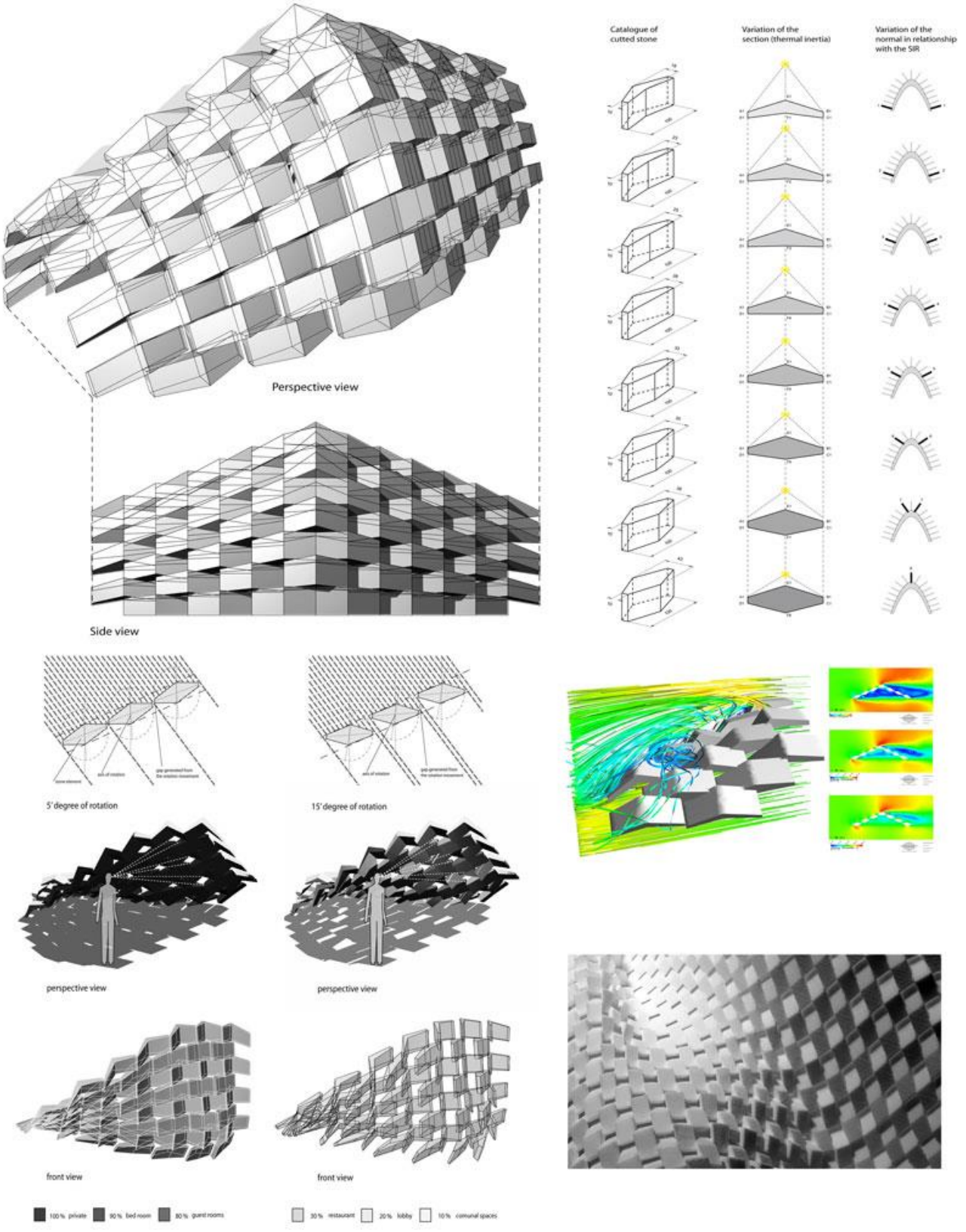

Figure 2: Parametric design modeling in progress scheme.

Genetic Algorithms (Figure 3) are used to explore large solutions spaces, finding optimal values with or without relevant variations of each variable. Executing optimization assuming all the variables together makes it possible to assess the relevance of final interrelations between them. The variables that don't vary in the optimal way do not influence the shape changing. ParaGen software

can be used as a tool for unite parametric modeling with Genetic Algorithms. It's interactive design allows exploration experience of different generated solutions by the designer. Search filters allow to store and investigate generated solutions in database, using any combination of variables or performance results.

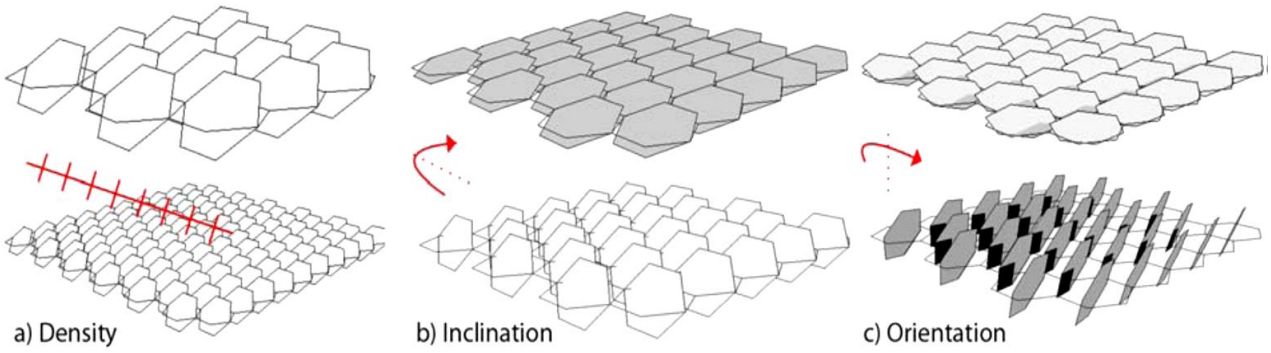

Figure 3: Genetic Algorithms.

Parametric search for geometric configurations with defined properties stands for determination of suitable configurations with predefined geometric design properties. In this case the structure constraints parameters variety, including relationships that are already identified as meaningful for the changes of performance. The exploration of design is narrowed down to search for specific configurations that the system requires under certain environmental conditions. This process can used to design adaptive roof structures that react of changing wind loads and to reduce the bending moment of the structure. Though this method has its' disadvantages it allows to search for configurations of responsive structures that show good performance. Considering responsive discrete systems, some possible structures cam be included. To choose a correct typology of structural behavior, the extreme configurations have to be defined, by determining the range of variability of geometry [4].

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