UN (RANDOM) ARCHITECTURE. CASES OF PARAMETRIC DESIGN

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Abstract

The development of computer technology and latest achievements in computer's software led to radical changes in architecture. These changes increased opportunity to develop innovative smart computer design based on special parametric programs. Algorithms and parameters introduced into programs led to increase variety in building shapes. This innovative approach opened up a new era in architectural history.

Precise designing is giving many fresh attitudes to the sketching process. In one hand the process of designing is getting easier and excludes functional mistakes. On the other hand this helps creating avant-garde, innovative shapes of the buildings. In this article the foundations and history of parametric design are presented together with the design approach of contemporary architects in this domain.

The article also discusses one of the issues related to teaching this methodology in contemporary schools. Based on projects from Technical University in Eindhoven (The Netherlands) formation foundations of parametric design are presented in the above context. The article further deals with the questions such as how much random is parametric designing, how big influence on final effect is based on architects work and how much depends on the computer. The research is divided into three parts, first, an introduction to the spatial designing and history of parametric design. Second - analysis of use of parametric design in contemporary designing. At last, a case study is presented based on parametric methodology in designing a Congress and Conclave Office Buildings with specific emphasis on the function, environmental aspects and form generation using computer software.

Keywords: parametric design, computer modeling

(НЕ) СЛУЧАЙНАЯ АРХИТЕКТУРА. ПАРАМЕТРИЧЕСКОЕ ПРОЕКТИРОВАНИЕ

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Аннотация

Развитие компьютерной технологии и последние достижения в программном обеспечении вызвали радикальные перемены в архитектуре. Все это создало возможность инновационного компьютерного проектирования, основанного на специальных параметрических программах. Алгоритмы и параметры, введенные в программы, позволяют увеличить разнообразие архитектурных форм. Этот инновационный подход начал новую эру в архитектуре.

Цифровое проектирование позволяет по-другому рассмотреть эскизный процесс проектирования. С одной стороны, процесс проектирования становится легче и исключает функциональные ошибки. С другой стороны, возможным становится создание авангардных, инновационных форм зданий. В статье основы и история параметрического проектирования представлены вместе с проектами современных архитекторов, использующих эти методы.

В статье также приводится проектный пример, который иллюстрирует обучение методологии параметрического проектирования в современных архитектурных школах. На основе проекта из Технического Университета в Эйндховене (Нидерланды) представлены

основы формирования параметрического проекта. Статья рассматривает проблему, насколько случайным является параметрическое проектирование, какое влияние на заключительный эффект оказывает проектировщик и сколько зависит от компьютера. Исследование разделено на три части. Во введении анализируется процесс проектирования и история параметрического проектирования. Во второй части проводится анализ применения параметрических методов в современном проектировании. В заключительной части рассматривается пример применения параметрической методологии в проектировании Congress and Conclave Office Buildings, с особенным акцентом на функции, экологические аспекты и формообразование.

Ключевые слова: параметрическое проектирование, компьютерное моделирование

There is no such things as chance; and what seem to us merest accident springs from the deepest source of destiny.
Friedrich Schiller

Introduction

Everything what is surrounding us is constructed by precisely defined rules and dependencies. All are related with the natural environment, as well as the civilized world created by the humans. Therefore, unsurprisingly we can find a series of frequency in every natural object. As an example we can take tree, where photosynthetic system is a drive machine for all processes and surfaces. The pattern of veins for the movement of fluids within the leaf shows that there is a mathematical relationship with the fluid distribution network of the whole tree. Similar patterns can be found in a human body- beginning from skin network, ending on our brain activity which is composed by trillions of pattern- perception and recognitions tasks. Moreover rules and dependences in human body are also stimulated by external factors. Most of the processes that occurs in living organism are precisely determined. An example of that could be the influence of sunlight on human body.

All functions and processes are regulated by day and night's rhythm. Research show that in human eyes there are receptors, sensitive to light. They also cause biological effect, such as hormone's production. One of them is melatonin which causes sleepiness and feeling of relaxation, whereas cortisol stimulate and give energy for activities. Thus the conditions are changing throughout the day. Moreover daylight regulates biological rhythm of human body. Because all processes in human body run according to defined cycle, for example: at 4 p.m. the heart action is increasing, causing higher blood pressure and temperature, at 6 p.m. kidneys produce more urine, at 2 a.m. in human body when there is the highest concentration of growth's hormone.

Apart from nature, algorithmically established patterns can be found well in architecture. It's not that they can be found in the domain of contemporary designing. The consistent configuration of model is noticed in style, ornament, decoration or geometry of building from ancient Greece and Rome to the present. In the Western or European tradition, pattern was deeply influenced by religion, geometry and mathematics (order, hierarchy, organization, scale, proportion etc.). The same thoughts were noticed in other disciplines like arts, design and crafts. "The concepts and theories through which spatial pattern was theorized include order, hierarchy, organization, system, scale, proportion, symmetry, balance, complexity, beauty, unity, function, decorum, representation, symbol, joint, nature, expression, imagination and creativity". (Garcia, 2009)

Order, ornament and decoration pattern was also practiced by many artists and architects. The main goal was to get symbolic, theological and philosophical purpose as well as enhancing the perspective space. A pre-modern architect which used spatial patterns was Vitruvius. He used optical pattern illusion and their affects. Such effects can be found in many pre- modern designs like the Great Mosque of Cordoba. Patterns are also used in Islamic architecture due to their philosophy (central metaphysical concept of *Nizam*). (Critchlow, 2004)

At present a new revolution is going on in the field of architectural design: **spatial-digital design**. In this revolution many architects and organizations are taking part but as a whole it's embryonic phase compared to the potential it offers. Despite that, spatial designing is already undergoing divisions. We can distinguish patterns designing, biomorphic and morphogenetic design (based on biological shapes and forms) and also parametric design (based on mathematical rules and forms). All of them are finding use in interior designing, urbanism and architecture. It is connected with firmly developed technologies where the work of an architects and artists is becoming entirely computerized. It's not only about using computer as a tool to draw sketches, it's about self-designing building's geometry by a computer programs.

Short history of parametric design

Every period in architecture is based on previous style. Gothic, baroque, rococo, modernism, constructivism etc. - there all are chronologically connected with each other. One is based on

another one, strongly depended on technology of construction industry of the time. Moreover every style in architecture reflects of times in which they were mostly used. Parametric design fulfils the same rule, but in contrast to prior styles, it has origin in mathematics. For parametric thinking we can establish the years of forties of the twentieth first century as the time of initiation. (Frazer, 1995) In that time the idea of creating an universal computing machine was proposed. First idea was posed by David Hilbert and later continued by English mathematician Alan Turing. He worked on a concept of reprogrammable digital computer.

This new approach to the parameters and its application was the beginning of the development of computer science. It was important step not only for mathematics but also for technology. Creating machine that will self-replicate given information started to be main goal for many scientists. Huge progress was made by Hungarian scientist John von Neumann whose research gave possibility of constructing first computer. Although it was based on basic parameters it initiated immediate development of digital designing. Computers become quickly a new tool of modeling. Research of Daniel Hills gave possibility to work out CAD system and computer modeling. It was significant tool for architectural designing.

John Frazer writes in Evolutionary Architecture: "Computer modeling is a method of virtual representation which provides a form of electronic prototyping. It allows ideas to be developed, described, visualized and evaluated in terms of environmental performance without the expense of actual construction or the time-consuming task of producing drawings". (Frazer, 1995) With this knowledge transformation from two-dimensional algorithms to three-dimensional object become only matter of time. First application of computer modeling in architecture concerned sun's geometry and shade of the buildings. It was first step how computer can not only support designing, but also make it easier and more precise.

Successive research was focused on improving designing software. Main goal was giving possibility to create digital models in comfortable and precise way. In middle eighties John, Julia and Peter Frazer studied on computer designing, which resulted in creating virtual models complemented in projections, sections and perspective's drawings. These researches on digital technology become a basis of parametric architecture. Unlike traditional designing, where first drawings are made by architects and then precisely introduced to the computer, parametric design is mostly based on algorithms and parameters where data can be actualized on many levels. It means that given information can be changed not only for parameter but as well as for all objects. This possibility of replacing data influences the final shape of the building. It may seem that parametric design is arbitrary decision of architects where designed buildings are not connected with surrounding. This is an erroneous opinion. Parametric design results also from desire to adapt building for surrounding and climatic conditions. Very often natural, curvilinear shapes are results of functional optimization of the building.

The current stage of development of parametric design is much to do with the computational design processes. It can only exist via the continuous advancement of techniques. However, the computer's geometry is reaching for more ambitions and goals. The agenda for parametric design still include new aspects for further extend into new styles such as parametric inter-articulation of subsystem (from single system differentiation to multiple subsystems), parametric accentuation (richer articulation and more visual information), parametric figuration (multiple readings can be constructed as a parametric model), parametric responsiveness (built environment thus responsive at different timescale) and parametric urbanism. (AD Digital Cities, 2009)

It's not possible to placed history of development and issues of parametric design in specific time's boundary. It's all the time developing, changing and undergoing further division. It's also finding increasing use in other industries but the main domain for parametric design is still architecture.

Parametric designing in architecture

During last century architecture has come through the metamorphoses. One was development of technology and modification in work methodologies and the other was significant changes in the construction industry through the use of reinforced concrete. The concrete become one of the

defining aspects of the 20th century. Designers easily saw the potential offered by new discovery and took opportunity to create structural forms. This achievement initiated next architectural breakthroughs. In the 21st century, technology took lead by pushing out traditional projecting and by introducing parametric design.

As mentioned, parametric design is practical use of computerized technology to create architectural spaces. Spatial forms are based on algorithm and parameters established by the designer. Forms, created in this way, are very often difficult to define by means of traditional building engineering. However it is finding use in practice thanks to special machines which produce desired details. Accurate example of this kind of designing is Frank O. Gehry & Associates office which is famous for complex, original shapes of the buildings (Fig. 1a). "In order to achieve the precision of the shapes and surfaces, it requires constructing in a controlled environment with machinery like CNC milling. Many projects that include curved metal wall panels, brick curved panels, and curved glass panels are actually built off site in a shop and then shipped to the building site and erected into place." (Blog of Michelle Kaufman http://blog.michellekaufmann.com)

Another architect who is using parametric design increasingly is Zaha Hadid. Her project can be characterized of curvilinear, dynamic form, imitated natural systems and natural morphologies. It is upgraded and realized through the introduction of digital tools. Designed forms became more intricate, more complex, more continuous and also on an ever-larger scale. Most of the projects are unify strangeness and beauty but the aesthetic values are also shifting to a certain extent (Fig. 1(b-d)). Values are re- evaluated and re-adapted to social, programmatic and urban conditions. In one of the interviews Patrick Schumacher, co- worker of Zaha Hadid, touch problems connected with the issue of unusual forms of buildings: "You are not used to seeing buildings like this, but the building you are creating is nearly nature-like: people accept these compositions, these spaces as elegant and beautiful, even though they haven't seen architecture like this before. (…)

There is also mathematics, new mathematics topological patterns and also what is having an impact is new modeling tools and more recently parametric modeling, parametric fields and scripted fields, you get a new sensibility with respect to orders of iteration. It fits quite well but it still feels quite continuous with the earliest works. Looking through these new tools there is a kind of intricacy of overall arrangement with a very high degree of coherence. There are a lot of internal laws of correlation; everything relates to everything else. It is a continuous change but it all fits together. It is not like a garbage heap. It's not random or arbitrary." (Blog of Zaha Hadid 2007/06/08)

Fig. 1(a-d): a) Frank O. Gehry, Case Western Reserve University, Cleveland (USA); b) Zaha Hadid, Art's Centre, Abu Dhabi (United Arab Emirates); c) Zaha Hadid Department of Herault, Montpellier (France); d) Zaha Hadid; Dancing Towers; Dubai (United Arab Emirates)

Parametric designing is not only used in process of designing buildings. It is also finding application in urban planning, interior design, industrial design or even fashion. One of the fashion designers that reach for digital designing is John Galliano. In 2009 he designed for Christian Dior special collection based on computer work. Innovative dresses that he presented become a new icon of fashion industry. The same effect is already noticeable in small urban architecture. Rocker-Lange Architects designed a city bench based on digital parametric models (Fig. 2). The model utilizes site information and programmatic data to react with the environment. In this way model's structure is capable of producing variety of original furniture. Thus generating new, endless line of outside furniture. (http://eng.totonko.com/2010/01/urban-adapter-rocker-lange-architects/)

Fig. 2. City bench based on digital parametric models designed by Rocker- Lange Architects

This new approach of looking on shapes and curves is all the time improving. Transformations are possible thanks to high advanced technology. Noteworthy is ShapeShift. It's an experiment in future possibilities of architectural materialization. This project explores the potential application of electro-active polymer (EAP) at an architectural scale. The ultra-lightweight, flexible material has the ability to change shape without the need for mechanical actuators. Shape Shift bridges gaps between advanced techniques in architectural design/fabrication and material science as well as pushing academic research towards real world applications. (http://vi meo.com/15368696) The new relationship between technology and designing are being realized. It's still a new approach of designing and only few Universities in Europe are taking steps to acquaint the future of architecture to the contemporary way of designing.

(Un) random approach to the designing

In this section, an example of parametric design is discussed which was a project realized during author's study at Technical University in Eindhoven (The Netherlands). A group of international students had to solve a problem of deadlock in the city center. The main goal was to design a Congress's Building which will become an icon of Eindhoven and will encourage visitors to stay longer in the city. The given spot was incredibly challenging because of functional mixture of neighborhood. From the south there is a commercial area with big mall and main city's promenade.

The characteristic of this side was entertainment function where citizens were not only shopping but also enjoyed themselves. Completely different setting is on the north- east side where the main intersection was situated. Big road with traffics, high intensity of noise and pollution were set with pedestrian precinct and bike's road. Moreover the main characteristic of this spot was central station for trains and busses. This place is equally used by the local citizens as well as by the visitors. These dependencies decided, at a later time, about positioning main entrance to the designed building and entrance facade. Lastly, (west) side of surrounded spot is an office zone. Mainly high-rise office's buildings are located there. Simple, austerely architecture which intensively contrast with the modern shape of shopping mall.

This diversity of functional zones creates a necessity to build functional model. First step was to establish what kinds of functions are needed in this Congress's Building. To get this information market researches were indispensable to make. Most of them based on current economical and development aspects lead to the decision about functional and architectural division. That's why students decided to design three separate buildings adequate to the selected functionality:

1. **Congress and culture zone** with assembly hall, auditorium and meeting rooms. For guaranteed use of building it were expanded with luxury restaurants and bars.

2. **Hotel zone** which include accommodation rooms, technical service (sanitary facilities, main hall, receptions, technical rooms, magazines etc.) with shops, restaurants and bars.

3. **Entertainment zone** where guest can find exhibition hall, sport centre, concert room, casino, cinema, theater.

Each of these buildings was open dependening on yearly cycle. During spring and summer, where more visitors come to the city, all of 'hotels zone' is functioning. It's also good season for entertainment. Congress zone is open few times in a year where diplomatic conventions are organized. These buildings differ from each other not only on functional aspect but also with quantity of storey and taken area.

The biggest space were given to the hotel's zone (23 500m² with underground floor), next to the congress and conclave area (13 400 m² with underground floor) and the smallest to the commercial zone (5 000 m²).

Second, was to arrange the location for function in the building with regards to the surrounding zones. Thus students built three simple, rectangular framework equivalents to chosen function: congress, entertainment/culture and hotel zone (Fig. 3). That model becomes the basis to further designing.

Fig. 3. Functional models. On the left: analysis of zones in surrounding area. On the right: basic functional models

Another objective was to create surface that will "wrap up" functional model. To perform this assignment students had to find some characteristic principles associated with the given spot. It could be analysis of bike movement in the surrounding, analysis of human body (way of walking) or analysis of found items around (like lifts, lost objects). In this case it was random 'search and find' based only on symbolic meaning. In the analysis four matters were taken in the consideration.

All of them were selected based on spot observation and which characterizes and represent the city as well as The Netherlands (rainfalls, shopping, telephone and refuge).

First one concerned the quantity of **rainfalls** on a yearly basis. The main goal was to find relations between time and water drop. Second, was based on **shopping** notes founded on the street. Analysis of inclination letters and intervals between words gave mathematics formulas. Third was about **mobile telephony** and range of given spot. The last one was response on high percentage of different nationalities. The issue based on **immigrations** in Holland during last decade (from 1996 till 2006). All of these researches were simplify the length and angle (Fig. 4).

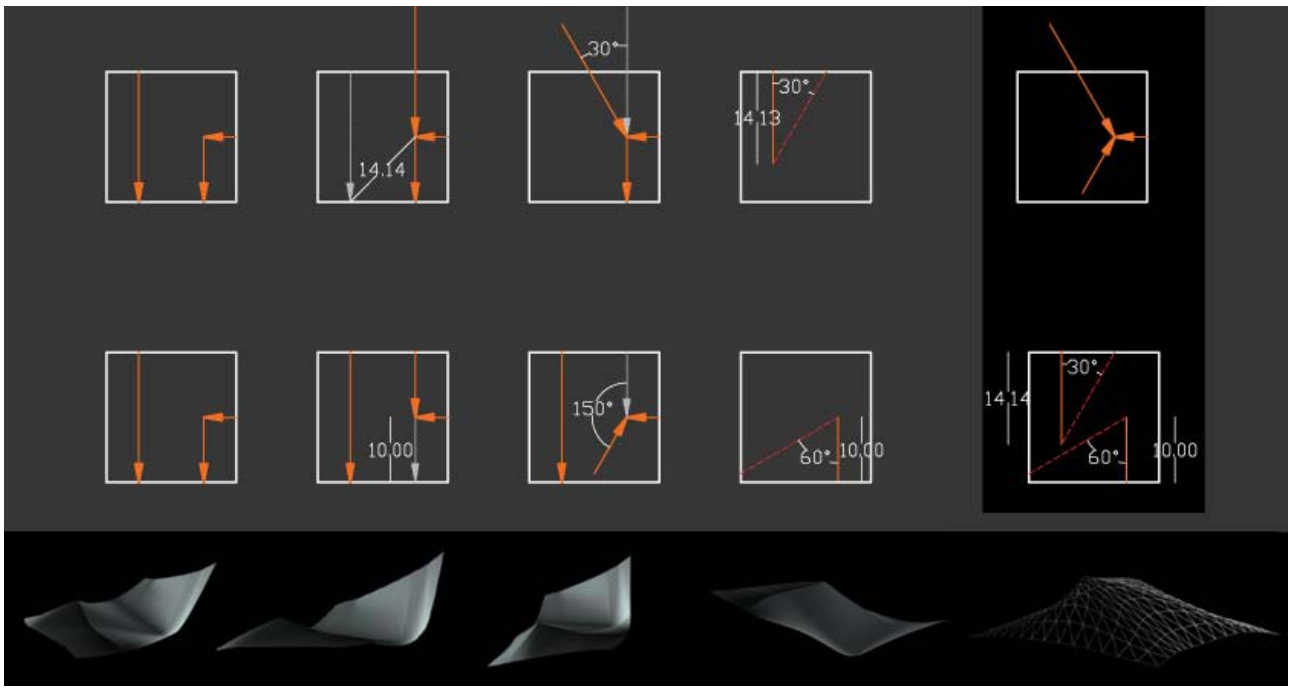

Fig. 4. Result of the all researches were simplify to three arrows with defined length and angle

These values were given as an input to the computer program, which used given length to define value of incision and fixed angle specified overlapping. As result program gave four different surfaces (Fig. 4). Subsequently all of them were divided by planes to get variety of shapes (Fig. 5 and Fig. 6). These shapes have been put on functional models that resulted the final geometry of the buildings (Fig. 7). End result was unique shaped building complex that was noticeable from city center as well as from central station. Each of the designs was unique, innovative and characteristic of the city. They gave new, fresh character to the city of Eindhoven. Moreover, to avoid traffic collision and facilitate access to Congress and Conclave Buildings, special footbridge was designed. Thus pedestrians could easily move from one to another side of the road.

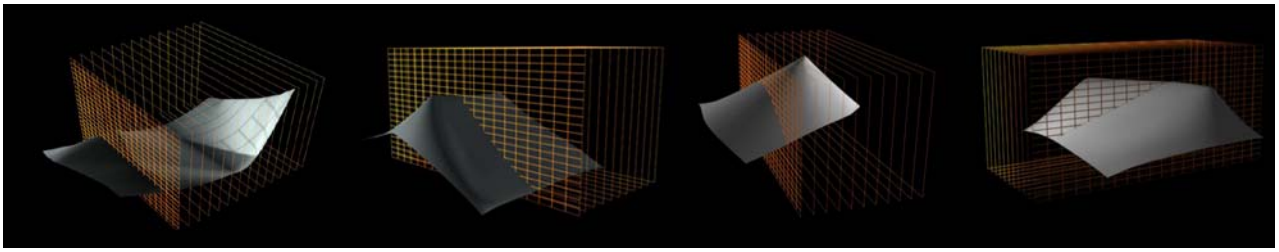

Fig. 5. Division shapes by planes

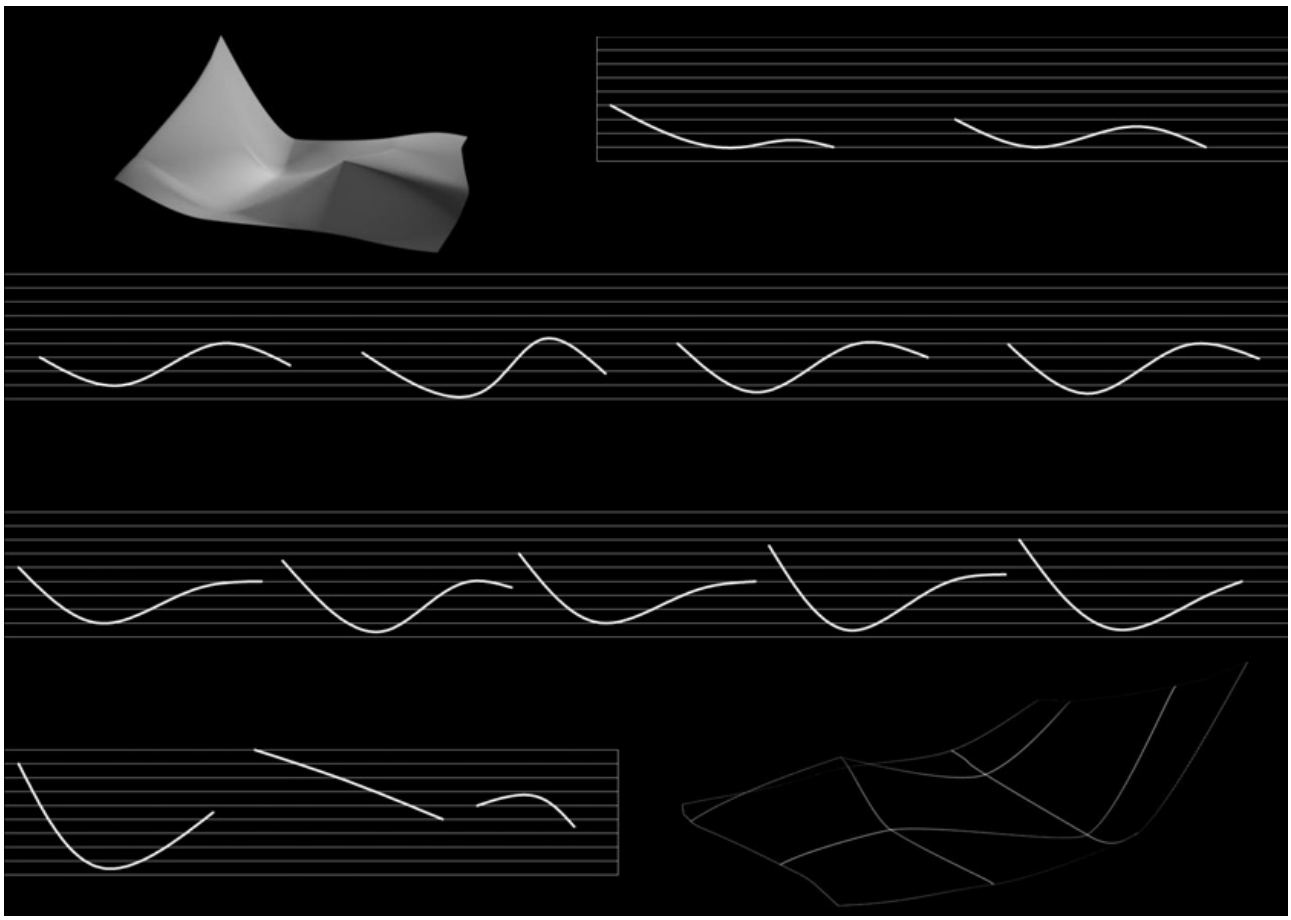

Fig. 6. The variety of simple shapes after division

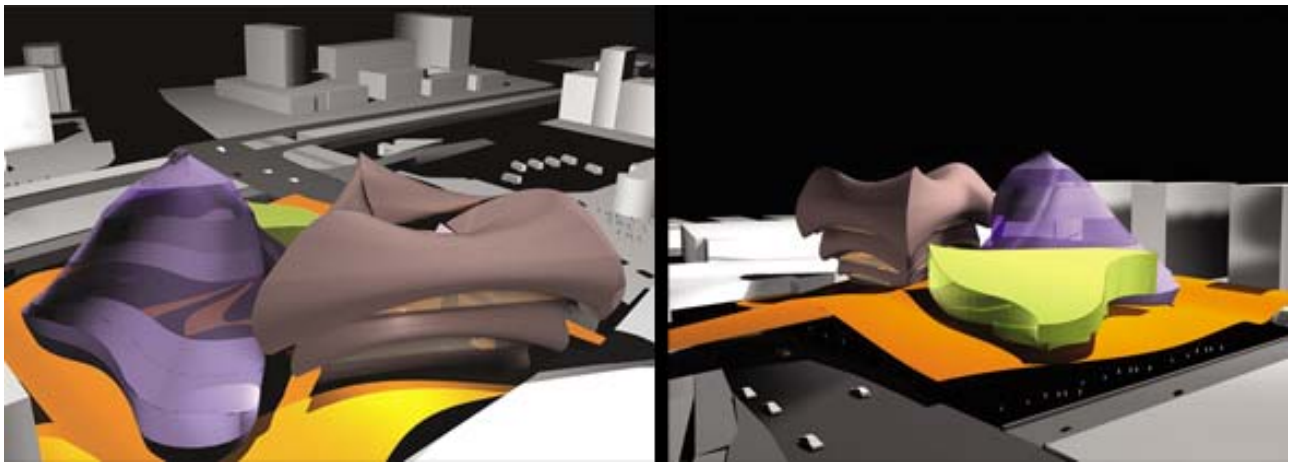

Fig. 7. The Congress and Conclave Buildings -Final effect of digital designing

The design was taken as an opportunity to explore parametric design. The experiences of studio workshops gave new insight in the contemporary designing. Context, scale and available technologies resulted in a combination of advance digital design. The eye opener was the fact that even from random found objects we can create un-random geometry.

Conclusion

Parametric design is still in its early phase of development but ongoing research shows that in the near future it will find its way into real designing. The development of new techniques is in this

case is a fundamental requirement for future success. The new way of designing is going to progress not only in technology but also substantive issues - creating new computer software, which will make designing easier for architects.

Sketching floor plans will be inseparable connected with reliable 3D visualization (more advanced than program like Revit Building are able to do today). Most of the clients will be able to see in early stage the ordered investment. The other side is that in developing architecture the human factor will become the most important. Functional mistakes will be totally impossible. However the most incredible is that computer development is giving birth to new architecture styles. Innovative look on the designing is determining its own place in the history. It's giving more possibilities for art, fashion, architecture and construction industries.

In parametric designing one of the most important issues is human factors. Digital designing should always consider the relation between generated building, surroundings and human factor. Some of the opinions claim that computer can't take under consideration the needs of the users and environmental requirements. To this end it is quite certain that parametric design will reach a level in the future where computer will start designing itself based on given rules. But behind every machine is sitting a man. He is the one who establishes (right/wrong) parameters for determined location, functions and the most important human factors related to the building.

Выводы

Параметрическое проектирование все еще находится на ранней стадии развития, но современные исследования показывают, что в ближайшем будущем оно будет внедрено в реальное проектирование. Развитие новых методов становится фундаментальным условием для будущего успеха. Новый способ проектирования развивается не только благодаря технологии, но также и новому программному обеспечению, которое сделает параметрическое проектирование доступным для архитекторов.

Рисование эскизов планов будет неотделимо связано с точной трехмерной визуализацией (более развитой, чем в современных программах типа Revit). Заказчики будут в состоянии увидеть заказанные ими объекты на ранней стадии проектного процесса. Одновременно в эволюционной архитектуре человеческий фактор станет самым важным. Функциональные ошибки будут невозможны. Однако самое интересное - то, что развитие компьютерной технологии рождает новые архитектурные стили. Инновационный взгляд на проектирование детерминирует свое собственное место в истории. Это создает новые возможности в области искусства, моды, архитектуры и строительной промышленности.

В параметрическом проектировании одной из важнейших проблем является проблема учета человеческого фактора. Цифровое проектирование должно всегда рассматривать отношение между объектом, средой и человеком. Некоторые утверждают, что компьютер не в состоянии учитывать потребности пользователей и экологические требования. Однако с полным основанием можно утверждать, что в будущем параметрическое проектирование достигнет уровня, где компьютер начнет проектировать себя на основе определенных правил. Но каждой машиной управляет человек, который устанавливает (правильные/неправильные) параметры для определенного местоположения, функций и самых важных человеческих факторов, связанных с объектом проектирования.

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