ABSTRACT

This thesis is an observation on the framework and methodological issues concerning the use of computer applications in design and manufacturing to support the development of projects in architecture and construction practices. This essay explores and presents digital design systems and realizing their usefulness, preconceptions, difficulties and advantages.

The design methodology evolves from manual into generative and thus extends the solutions, allowing complex operations. The generative process is oriented so that the results are close to the predefined objectives. These tools come from many areas of design and creation, being used in architecture and design process, being used in every scale, from the scope of the building to the city.

This theoretical approach aims to understand and deepen the concepts inherent in new technologies, realizing their applicability within examples of projects undertaken by contemporary architects.

Secondly, it’s presented an academic project developed along the discipline of Architecture IV, using digital tools, whose theme refers to the exploitation of a new concept of living linked to agricultural activities, setting rules and limits for a master plan.

Key words: Generative Design, generative Project systems, Parametric Architecture, Parametric, Parametric Urbanisms.

1. INTRODUCTION

1.1 Framework

This new way of conceiving design, intended here as parametric architecture, gets its name from the term “parameter”, which can be assumed as any element whose value or its variation implies a change in the final product, but without changing his nature. Parameter may also be understood as a limit used for monitoring, obtaining a particular reaction. It is curious to notice that the term already appeared earlier in the architecture vocabulary, such as the land use and in the definition of the urban fabric. However, currently it explores more advanced tools of computer aided design, aiming to follow the design process and generate
forms in a more interactive way, where parameters are manipulable, allowing the model to be adjusted more easily.

During the last years numerous works arise based on the use of these new tools, contributing to the discussion around the "parametric architecture". This trend is called as style: "parametrism" by one of the largest users of programming tools: Patrik Schumacher. Parametrism present in other areas related to the design and it may be the next great style after postmodernism and deconstructionism. (Schumacher, 2008) The increasing use of these tools, especially applied to urban design, has its origin in a massive demand for restructuring projects and rehabilitation of cities, which were seeking the customization and uniqueness of each city, in order to generate innovative and attractive urban environments.

1.2 Motivation

The motivation for this research work arises from the contact with a different way of design, using new drawing tools and concepts that until now were unknown. Thus, this work is an opportunity to acquire new knowledge, facing the reality of evolution of the design process and new design possibilities, brought by Digital Processes Project.

For some designers and architects, these processes are already introduced in early stages of their research, so they acquire the basic concepts and realize the way of thinking that these tools require. On the other hand, a large majority of professionals and students in the areas of design and architecture remain with traditional methods of design, i.e., where the only tools used for the design process are hand drawing, the models and the vector representation with CAD programs. Therefore, it remains indifferent to the growing reality that successively changes the design and construction process.

In this way, one motivation for this thesis involves the understanding of what is currently happening in the digital world, obtaining a comprehensive overview of new technologies and their applications, such as new concepts and changes introduced in design processes, realizing its benefits. However, there is no such question as which method is the most valid, because the purpose is to take advantage of the two ways of project evolution and the benefits that each one brings.

2. METHODOLOGY

To fulfil these goals is made an investigation of Digital Processes and their context and methodologies. It’s possible to make a distinction between Planning and Manufacturing Technologies, where planning technologies studied were GIS\(^1\), Infographic, simulation and optimization, CAAD\(^2\), parametrism, digital capture systems and communication and collaboration, namely BIM\(^3\). In what concerns manufacturing processes, these can be divided into three types of processes, additive processes (such as rapid prototyping, CNC precast concrete, robots aided

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\(^1\) Geographic Information Systems - is used to capture, organize, process, analyze and spatial information representation.

\(^2\) Computer-Aided Architecture Design - is used as part of design processes as a way to generate design documents, based on specific software for this purpose. These programs can be characterized in 2D, 2½D and 3D CAD (Hauschild et al., 2011).

\(^3\) Building Information Model – is a model representative of all construction data. Thus, in addition to being able to manage 3D data, it is possible to access all components information.
assemblies), subtractive processes (e.g., laser cutting, jet cutting, hot wire cutting, CNC milling) and formation processes (e.g., CNC bending edges, and punching CNC forming pressure and nibbling). There are presented various tools and concepts inherent to their practice, demonstrating their potential in architecture.

To understand the fundamentals of Digital Architectures, some projects are studied, where it’s possible to understand the origin of the use of these tools and in which ways it was beneficial, it is used documents prepared by the pioneers (Utzon, Michael Wilford and Partners, DP Architects, Bernhard Franken Architekten, Gehry and Partners, Zaha Hadid Architects, SANA Kazuyo Sejima & Ryue Nishizawa, Szymborski Architectes, Toyo Ito & associates) using these tools. They fundament and reflect about each step and theorize each advance they make.

Then, a theoretical approach to Parametric Urbanism is made as introduction and conceptual preparation to the case study, mentioning his fundamentals (e.g. the idea that the territory is not static, but a field of forces, that is able to change the project) and new logic introduced by this way of urban thinking. Here, the digital tools are used for research purposes and enable a new architectural approach, identifying characteristics such as diversity, adaptability, and responsiveness (Kolatan, 2006). This urbanism explores new methodologies such as, shape grammars\(^4\) and diagramming.

To explore the context of urban planning, some projects were analysed (Urban Project for the Rebstock Park, Landsberger Allee Urban Project, Almere Masterplan and Euralille Master plans, Trafalgar Square, One-North Master plan, Kartal-Pendik Master plan, Thames Gateway Master plan, Zorrozaurre Master plan), demystifying that Parametric Urbanism is limited to formal design, disregarding spatial needs of man. Therefore, it is presented a new way of city thinking.

With the case study comes the opportunity to expose a first contact with computer aided design tools, demonstrating the gap that exists in the current project teaching, basing on studies and experiences reported by students and teachers of this discipline.

To mitigate barriers between users of both methods and to see that it is possible to benefit from the advantages of the two strands, it is made the account of the case study, which has benefit from both design methodologies. To reinforce this theory there are exposed other studies and experimental explorations.

3. CASE STUDY

Context

The EPFL Architecture course is organized by ateliers with teachers and specific projects. Each atelier is a design curricular unit. In other words, the projects developed in the ateliers and the way of knowledge transmission is part of a broader research.

RE-FARMING BEIJING – PARAMETRIC FOOD IN PERIURBAN-CINA

The chosen atelier aims the introduction of new technologies in education. This research lab seeks to give students the idea that the use of computers in architecture is not exclusively a way of producing renders, but a way of designing

\(^4\) The formal grammar was developed by (Stiny & Gips, 1972), in the early 70’s, and is a based rule system for generating forms, seeking flexible urban systems.
machines that allow the creation and experimentation forms impossible to draw by hand. More than a precise final form, the most interesting here is the variety of solutions that parametric formulas can generate, being able to use the adopted programs in all project scales. The goal was to use Grasshopper programming to build the project, creating variations during the design process, without excluding/abandon the traditional methods such as hand-drawings.

The project proposal had as a goal the construction of a Fabric in China, something between building and territory, without bearing directly not dealing with on the master plan, but instead, being related to a part of it, as an unfinished model that can be connected and create variations. A condition for this fabric was the integration of agriculture and housing. In this way, the discipline was organized in two moments, the first with an abstract character, where the rules have been developed without regarding the site, and a second moment of intensive work on the territory and adaptation to context.

Sketching ideas and intentions, reaching for rules

Initially, there was no use of programming tools, although its study and work had already started. The use of manual methods was encouraged by teachers as a crucial step towards the clarification of ideas and intentions. Thus, there were developed discussions around hand-drawings and models for the exploration of ideas and concepts. Here, it was explored the methodology of grammatical forms.

The next step was the creation of percentages and occupation ratios, measurement and division of plots (Image 1), analysis and data processing of the urban agglomeration as components. Thereby, particular characteristics were extracted from the project, to develop and realize its benefits. In addition to this, was presented a project thesis:

Agriculture emerges between buildings, where both become equally related to each other. This green agriculture can be divided into two types: Green Community (yellowish green), where the concept would be the promotion of community work, and private green (green) associated with a single use. Between buildings and agriculture, there is public space (blue), as locals to socialize. It is studied how different types of greens can influence the creation and change of housing (white), understanding how to get benefits from them.

![Image 1](image1.png)

Image 1 Ratios and measurements of the plots.

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5 (Urban Fabric) is the physical form of cities and towns, such as textiles, fabrics can be of different types.
With this excerpt, it is possible to understand there is a concern in creating public spaces for social gathering, managing the flows along the fabric, constituting one of the underlying principles of parametric urbanism.

Abstract Phase

Although the fabric continues "deaf" to a context, there is a great potential of variation control and possible adaptation to different contexts. An important factor is to know what is intended to create, in other words, there is a need of clearly defined the rules before starting the code, that is why the whole earlier diagramming process and developing ratios was so important, in a way that it forces a constant process of clarifying objectives and rules.

An essential element for all presentations was the conceptual diagram, which seeks the most effective way to represent the project concept. In this diagram (Image 2) it is possible to see spaces, green areas, and building merges (marked in red), something intended from the beginning. To achieve this principle, each parcel has a percentage of each space type, which comes together to form larger spaces (Image 3).

There are benefits to sketch diagrams in a digital environment, it enables the sharing and development of drawing intentions more extensively, exposing the diagrams and receive contributions from others. It is sometimes difficult for students to detach the literal translations of the diagrams and understand that the production techniques of diagrams can be used as generating programs or starting points of the design processes, where the intentions or relationships are first established.

Due to some code difficulties in making form variation as shown in the following diagram, it was decided to simplify the forms, using "L", as visible in Image 3.

The Grasshoper code arrises in relation with these thoughts. It follows the same logical steps, i.e., we started by creating a typology and internal relations of a plot, which correspond to the ratios of each type of space (built, social space, green private and common). Then the code divides a surface into several parcels, according to a mathematical formula that could be changed through sliders. This is a choice made due to an inexistent design context. When having an artificial terrain subdivided into plots, there is a need to define external relations that are achieved through attractors and activators - elements to whom all the fabric responds. At this stage, the attractor is an imaginary line that joins lower ground points, where are located the larger parcels and better active social life. For this
implementation, the closest points of each plot to the line of attraction are extracted in a list. In each plot is inserted an "L" shape, where public space is the nearest quadrant to this line (Image 3). At this point, it was given a volumetric constraint, which varies in function to distance from the line (that represents the public space), making it higher when moving away from it. Despite the achieved volumes are not the sought solution - due to the inability of handling the programs - it opened and generated a lot of discussions, creating openness to the dynamics that occur constantly throughout the process.

In this way, with the encoding concept (Image 4) it is demonstrated the ability to create variations within the same principles, where have arisen new ideas, after overcoming firsts program difficulties. The project acquired another dimension and responsiveness to different situations, non-existent so far (Image 5).

Context Adaptation

CHINA CONTEXT

Growth in China is exponential, with a current population of 18 million, it is expected to double in the next 30 years, resulting in the need of finding new strategies. The Chinese government takes action to control the growth of cities and urbanization plans, where Food urbanism arises as a possibility, a strategy being used in several cities. In this way, the atelier proposes the concept of Parametric Food Urbanism as an alternative.

At this moment, the sliders and parameters implications in the proposal spatial quality became clear. Therefore, some goals must be revised, adapting to the given context. The objectives consist of: regaining formal and spatial variation lost by technical
difficulties; and include a wider transport network, which would link multiple centralities. Each portion of fabric would have a centre, which is related to the other centres, through the imaginary line that symbolize public space, i.e. the centres of various fabrics are the main points of social activity, being related to each other.

The chosen site to intervene is near the river, bounded by mountains and it is related to a satellite city, which will be taken into account during the process (the following images illustrate the process).

**Image 6** Interpolation drawn manually of topography lines in Rhino. These lines will be one of the guidelines for the creation of the plots.

**Image 7** Water lines (blue) and ridge lines (green), which have an active role in the organization of the plots and the type of occupation. The red line (pedestrian line) unites urban centres with higher social life. It is an important line, to which the whole fabric reacts, so by changing this line the fabric changes immediately.

**Image 8** Based on hydrographical lines were defined (in grasshopper) agricultural areas around the water lines (green) and residential areas (in red). Residential areas were classified and coloured (from light red to dark red) according to the distance of each parcel to the pedestrian line, being the darkest one the furthest.

**Image 9** Typological variation in accordance with the principles shown in the diagram of image 12.

**Image 10** Map where it's possible to understand the typological variation, different greens and streets that have been established.

**Image 11** The definition of heights also varies depending on the distance of each parcel to the red line (public spaces).

The typological logic sums up the initial diagram and gives the site orientation (Image 12), i.e. the public spaces are organized along according to the red line location (light green). Public spaces are associated to cross-shapes, to have a greater ability to connect and create socializing and meeting places. Toward the river typology evolves into a vertical form, in order to create great visual permeability, and toward mountains it evolves into a horizontal form, adapting to the terrain and following the topographic lines (Image 10).

**Image 12** Final Conceptual Diagram, which was rotated to match the orientation of the terrain.

Notice that when changing the position of the red line, endless variations occur within the same principles, being also possible to control the rate of change between vertical and horizontal shapes. In a similar way, by changing the
geometry of the plot, i.e. the topographic lines, water and ridge lines, will result in a different design.

The number of stories was set with Grasshopper (Image 14), but the formal variation in height was partially made by hand with ArchiCAD, due to the limited time available to finish the code and produce all the required elements for the presentation.

The variation that occurs in plan also exists in section?, creating diversified balconies and terraces, as well as spaces at ground level with different ceiling-heights. Image 13 shows a set of possible buildings, represented by each level plans and the result from of the overlapping of plants.

Image 13 Each horizontal line corresponds to the change from floor to floor of a building. On the right, in gray, there are the plants of the resulting buildings.

Image 14 Code for the entire evolution of the conceptual design, which was used in mapping preparation.

Regarding the code partition shown in Image 14, it can be seen that for each step or design intention, there is an associated code, i.e. the code corresponds to the project idea, leaving room for variations.

Once the desired code definition for heights was not performed on time, the first portion of fabric was not produced in ArchiCAD, as well as the physical model. However, the time required to execute the code and automatically produce presentation elements would be much less than the time required for manual production. It is noted that it was only possible to perform by hand, during one week, because it was accomplished only 1/6 of the fabric. On the other hand, having the full code would allow extracting the entire fabric (physical models, renders and drawings) as well as numerous variations within a few hours.
4. EVALUATION OF RESULTS

All the prepared research on the processes and concepts becomes important a priori, given that is initially difficult to realize which way and logic thought should be followed. On account of the lack of concepts and comprehensive understanding of digital technologies, some choices were taken up during the process, which would happened differently if this information was already pre-acquired. It could be provided a better exploitation of the course. For instance, the code preparation followed longer paths, due to bad understanding of the organization logic.

Despite the difficult of insertion in a digital thinking and programming, it is even harder to detach the reasoning from this digital thinking, when is aimed to present the project to other architects or other professionals. During a presentation is completely forbidden the use of technical names of programmatic language, as it should transmit the meaning of these values and their changes, as well as what they bring to the project and its quality for the urban space.

Something that influenced the technologies efficiency was the lack of time, therefore faced with the need to have finalized the presentation elements, decisions were made to simplify intentions and consequently the code. However, when the necessary levels of programming are achieved, there are new variants and new unexpected ideas that can take the project to other directions, never met otherwise. Despite the difficulties, what was done digitally would not be impossible to perform manually, and the project would have been completely different.

Were suggested by the teachers some aspects for further development, such as the vertical relationships between spaces and go further on the level of detail and relationships of internal circulation. Therefore, for following proceedings, it would be interesting to keep on setting new rules, increasing the level of detail in typologies and internal relations. Other aspects to be developed would be: automatic creation of plots, based on the topographic, water and ridge lines; development of various types of analyzes and simulations that would lead to re-happing and adjusting the project and its rules, namely spatial analysis. One final interesting aspect would be the development of a model from a BIM model and exploitation of digital manufacturing processes, something that was thought in the beginning, but not getting to be conducted by the time restriction.

This project was an extremely enriching experience, which led to the discovery and study of a new way of creating architecture. It showed that the absence of conceptual bases can difficult the approach to these complex technologies, it is yet possible, thus leading to an autonomous work of research. It also showed that it
is perfectly feasible the articulation of both methodologies (digital and traditional). This combination of approaches led to project quality and increasing growth.

5. CONCLUSIONS

A classroom for project design is different from the conventional classrooms, where the teacher offers his knowledge to an audience. In the design studio environment it is possible to experience accumulated knowledge under the guidance of a teacher, where the learning process is performed by the students. Even if the teacher holds the knowledge, he does not know what will be the solution found by the student, making it impossible to pass on the knowledge that the student is unable to absorb. This type of reflective knowledge can be a model for other areas, but it is clear that the design disciplines are in a constant state of crisis and renewal (Brasil, et al., 2009).

Architecture and Urbanism teaching tradition has its guidance on valuing and organizing scientific areas, where students learn a range of theory, history, design and technology disciplines. New technologies have transformed the possibilities of producing knowledge and its transmission, since it is possible think of new ways of ordering knowledge associated with new ways of conceiving learning objects. "It is imperative to innovate forever and learn to network, building experience laboratories that incorporates new performance spaces to expand the dialogue of research and education centers in architecture and urbanism" (Egier & Neves, 2004).

Methods Integration

The computer is more than a tool. It opens a new architectural era, in which the design methodology will experience major transformations and the results will point out new directions and possibilities in architecture, thus after the industrial revolution, comes the digital revolution (Alves, 2009). When understanding the creative potential inherent in these tools, a new architectural language is established, creating new expressions and new spaces.

The drawings and sketches are used by architects and designers as a way to develop thoughts and ideas about design problems. During abstract initial phases tools of analysis, expression and representation are necessary, being the drawings and sketches the chosen tools. However, the sketches are much more than simple tools of representation, they are a dialogue between the designers and the drawing, helping to develop and enrich the concept, at a stage when it is given less importance to detail. However, the important factor is to externalize thoughts, being able to create and study ideas (Alcaide-Marzal, et al., 2013). In this sense, this consideration opens the doors to the use of other tools, including computers, which allow exploration of a new and alternative forms variety.

The integrated use of technological and traditional means is beneficial to the teaching of architecture, which should be taken as fact, without denying the rapid evolution of technological means:

“Today, it is believed that, as the drawing hand is an activity inseparable from the process of reasoning that leads to the project, a similar phenomenon can happen as using other processes of representation as allowed by digital tools. These tools, whether analogical or digital, are a way designer use to establish a dialogue with their own work” (Duarte, 2001).
Timeliness

Nowadays, it is an important aspect the ability to navigate complex and dense urban environments. The Post-Fordist society requires a continuous connection, information, and insulation is not a hypothesis, when innovations emerge every moment, where architectural expression is a “field of simultaneity”. The architect must adapt to this innovations and act intuitively understanding the urban design as an opportunity to design a new, coherent meaning system, a new architectural language. In these new environments, it is essential the planning and design of an innovative media. The architecture and urbanism provide articulating system of definitions, which brings together participants from social interaction in prestructured communicative situations (Schumacher, 2011).

Final Comments

The architecture project has a long tradition of using different types of drawings, diagrams and sketches as part of its process. Sketching for the architect is not just a translation of the author's thought, but a way of influencing his thinking (Góes & Menezes, 2010).

A “digital atelier” in this context appears as a space where is needed a proper integration between traditional and digital resources. The various methods, means and technologies could be employed in a complementary and optimized use with emphasis on what each resource has to offer for each moment in design practice, in which technology is a facilitator and the design is a catalyst, considering that they are used in a well programmed environment.

The results of the research prove that architects, especially in an early stage of the project, establish a stronger and deeper interaction with their own sketches. This interaction with the drawings is more relevant for architects than the physical ability to draw. The sketches support the emergence phenomena and reinterpretation during the first activities in design process. Emergence refers to the thoughts and ideas that could not have been planned or anticipated prior to execution of the sketches. Reinterpretation refers to the ability to transform, develop and generate new images in mind while designing. Thus, if the emergence of new ideas and imagination can be extended using sketches, there is no reason to assume that they also cannot be extended by the use of computers.

In this new way of designing, unlike in the past, architects do not draw under a treaty, which validates the projects, since now it can be mentioned a treaty Digital. Treatises changed, there is no physical document, in other words, they are the digital tools used as research means, generating new concepts available to architects, who have the freedom to explore and make the most of it, thus able to achieve new modes of spatial perception, new relationships and new conceptual and theoretical procedures, changing the construction and project processes.

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6 In general post-Fordism concept is used to define a model that differentiates productive management of Fordism, as regards, in particular, the organization of work and production. Thus, instead of focusing on mass production characteristic of Fordism, post-Fordist model is based on the idea of flexibility. Therefore, works with reduced inventories, turning to manufacture small quantities. The purpose of this form of organization is to meet the demand placed on the exact time, as well as serve a distinct market, endowed with public increasingly specific. This allows the industry to keep up with rapid changes in consumption patterns.
BIBLIOGRAPHY


