Parametric design

Tool, medium or new paradigm?

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Parametric design is an emerging research issue in the design domain. However, discussions about the creative process in parametric design are limited. What is more, despite the passing of 57 years of parametric design’s existence we still do not know what parametric design is. Is it a simple tool, which is useful in some kind of optimization of the architectural form, or is it a medium, which helps architects develop unexpected solutions, and perhaps this is already a new design paradigm? The presented paper will contain general considerations relating to the nature of parametric design, the history of which starts in 1960, when D.T. Ross has formulated the thesis that our main objective is to formulate constrains and all needed parameters of the solved problem. Please write your abstract here by clicking this paragraph.

Keywords: optimisation, parametric design, design tool, design media

HISTORICAL BACKGROUND OF THE PARAMETRIC DESIGN

As a result, the development of a design methodology, caused by the increasing complexity of both the object and the design process, as the main principle of improvement of architectural design approach has focused on the objectivization and rationalization of the design process. The main principle was defined as follows: "When we know exactly what is and also exactly what ought to be we are able to establish a direct efficiency relation. By appropriate comparisons of what is and what ought to be, efficiencies, both ideal and practical, can be established." (Emerson 1964, p. 23)

The first attempt of applying something like parametric design was undertaken in 1960, when D.T. Ross in Computer-Aided Design: a statement of objectives, has formulated the thesis that “...we now declaim that our main objective is not to solve problems, but to state problems”, which meant to formulate constrains and all needed parameters of the solved problem. (Ross and Mann 1960) The first computer program conducted under the Computer-Aided Design Project was written by Ivan Sutherland in 1963 in the course of his PhD thesis at MIT. In the following years research has focused on the problems of how computers can aid the facility layout process and the designer’s interaction with multiple design databases. The classical layout programs are: block diagramming software - CRAFT (minimizes nonadjacent cost and used when quantitative data is available) and relationship diagramming - CORELAP (based on location preference between areas and used when quantitative data is not available). (Lee 1967). CRAFT: Computerized relative allocation of fa-
facilities’ technique (Buffa, Armour and Vollmann 1964) was one of the most popular computer based layout procedures. Algorithms elaborated by Buffa et. all, based on the heuristic approaches, were used to place factory spaces in a way which would reduce the total material transportation cost. The cost was a parameter defined by a function of the distance between work centers, the frequency of movement of material between the centers, and the cost involved in each move. The algorithm starts with an initial layout and proceeds to improve it by interchanging spaces in pairs to achieve its goal. The combinational problem lengthens the solution process as the number of work centers increases. If designing layout for 20 work centers, exchanging two work centers simultaneously, would require 190 evaluations. Exchanging three work centers simultaneously increases the number of evaluations to 1140, and if we would like to change 20 centers it would need n! - 20! evaluations. With this amount of points, making changes manually is practically impossible.

The time requirement for a computer is trivial for an evaluation of these possibilities. This technique permits a considerably larger number of evaluations in a short time. It does not give the optimal layout; but the results are good and near optimal, which can be later corrected to suit the need of the layout planner.

CORELAP: Computerized Relationship Layout Planning is the oldest Layout Planning routine and was developed by Lee and Moore. CORELAP generates a layout on the basis of the total closeness rating (TCR) for each department and begin with two major inputs: a relationship chart and space requirements. The starting point is creation of the Muther’s grid table which displays designer’s preferences for relative (pair-wise) department locations. Muther has proposed a six points scale: A - absolutely necessary, especially important, I - important, O - OK, U - unimportant, X - undesirable. To obtain a layout, the user is required to input the following: number of departments, relationships weights, relationships cut-offs, partial adjacency value, and relationship. Then the computer generates the layout. The total closeness rating, the order of entry of departments in the layout, the numerical closeness value and distance between the departments are also shown. CORELAP accepts relationships between as many as 40 departments. (Lee and Moore 1967) The new version of the CORELAP algorithm can be obtained from Tompkins et al (2003) where a new interactive version of the software is presented. The user interface in this implementation of CORELAP is the spreadsheet and the user inputs data through Microsoft Forms. In 1980, the author has in his diploma work used the routine, a modification of CORELAP, developed by Maria Ostatrowska in 1977. The diploma subject was a Primary School. As the first step the functional program was defined and it was decided that the school should consist of 9 areas: A - Library, B - Classes 1-4, C - Mathematics and Environment, D - Humanities, E - Technical Lab (DIY), F - Art, G - Sport, H - Recreation, I - Administration. In each area, different functional blocks were placed, and as a result a matrix of 40 x 40 elements was obtained. Connections between the elements were evaluated on the basis of a 4-point scale: 1 - direct connection, 2 - strong connection, 3 - medium connection, 4 - weak connection. These values were the design parameters. Due to hardware limitations, this large matrix was simplified to a symmetrical matrix of 9 x 9 elements, which meant that firstly the location of the 9 school areas was calculated - the computer produced a graph which graphically represented the links between main functional elements. The same procedure was then repeated for areas A, B, C, H and I. As a result a comprehensive scheme of functional links was created. On the basis of the schemes the building plan was created manually. To get many variants of the plan, values of the chosen parameters were changed, and matrix was calculated again. (see Figure 1) Practice has shown little usefulness of these methods, especially if the laboriousness of preparing data at the initial preparatory stages is taken into account. It was not possible to apply subjective parameters, which led to oversimplification of the plan. These programs were characterized by a primitive input and output as
they worked on the principle of batch processing. The old programs were very user unfriendly. Despite the difficulties caused by the imperfection of computer hardware (time consuming batch processing) and simple software, the relational method was helpful in designing the building plan. It should be noted that with the development of computer technology, these programs have become one of the basic tools for industrial facility planners. This has profound effects on organizational productivity and profitability. Optimal layouts reduce materials handling costs, help streamline all operations in a facility, and reduce energy costs. With large amounts of money being spent on new facilities each year, it is natural that industrial facility planners, designers, and architects long for a superior Facility Layout Optimization software. On the market, we may find many professional computer programs for Layout Planning. One of the interesting layout optimization tool is VIP-PLANOPT (formerly known as Layopt). This software is an improvement algorithm for developing alternative and efficient block layouts from an initial block layout provided by the user. In the absence of an initial layout, one may be also randomly generated by the program. The algorithm used in the program is based on the algorithm developed by the Bozer, Meller and Erlenbacher. It extends a well-known facility layout algorithm (CRAFT) to facilities with multiple floors. It also enhances CRAFT by controlling department shapes by allowing flexible departmental area requirements. (Bozer, Meller and Erlenbacher 1994) BLOCPLAN is an interactive program developed by Donaghey and Pire. Quantitive and qualitative data can be used as input. It can develop a single story or multi-story layout. As the BLOCPLAN generates an initial layout and makes enhancements of this layout, it can be explained as both a construction and an improvement method. The user may optionally choose the random construction and automatic search. (Donaghey and Pire 1991) Micro CRAFT (MCRAFT) is an extended version of CRAFT, presented by Hosni, Whitehouse and Atkins. MCRAFT divides the plant area into bands and assign these bands to one or more facilities. Moreover, MCRAFT eliminates the pair-wise exchange limitations. By using MCRAFT, all pairs can be tried with the pair-wise exchange method, which makes a large contribution to finding an optimum solution. (Hosni, Whitehouse and Atkins 1980)
PARAMETRIC DESIGN AS AN “OPTIMIZATION TOOL”
All computer programs discussed above are a kind of an optimization tool, the goal of which is designing a cost-effective product in minimum time. In order to achieve this goal, the requirements of optimum designs are becoming more important. Parametric design modelling platforms and scripting environments allows for rapid generation of 3D models and enable multilevel evaluation of parametrically-driven design alternatives. The key to understanding what is parametric architecture, is the word “parameter”. Design is based on carefully described parameters, which are used by computer programs for generating original, unusual and difficult to describe spatial forms with mathematical precision, optimizing them mostly in terms of environmental or functional conditions. Parametric design is treated as an “optimization tool”. In architectural design, different parameters were used to “optimise” the architectural form. Each parametric design starts with a parametric variation, which can be employed for the differentiation of a field, layer or subsystem. The most common are the parameters associated with the structure of the building, energy efficiency, sun exposure, location, acoustics or aerodynamics. This is fully understandable because, for example, in the design of high-rise buildings the cost of “architecture” is only 40% of the total cost, MEP (mechanical, electrical, and plumbing) - 25%, structure - 30% and elevator system is 5%. (Nicknam and Elnimeiri 2011) In the current design practice, issues described above are typically left to be dealt with after the architectural form is well articulated. This approach is time consuming when the architect proposes multiple options. The solution is a full integration of optimization tools with the CAD system, where all drawings can be automatically updated after achieving the optimum and satisfying all imposed constraints. The advantage of this way of working is a shortening of the optimization cycle time and radical reduction design time. Another advantage of this approach is also the ability to reduce investment costs, as the most important design decisions, which have the most significant cost impacts, are made at the concept stage of a project. The serious disadvantage is that parametric methods are mostly used at the stage of detailing of the project when the designer may update the CAD model only after receiving an optimum design from optimization tools. Consequently, in traditional Computer Aided Design the main consuming factor is the design optimization cycle.

PARAMETRIC DESIGN AS A DESIGN MEDIUM
In 1994 Ranulph Glanville has asked: “What is the difference between a tool (or toolkit) and a medium?” and then answered: “The difference is that the tool does what we want, amplifying, in some sense, our natural abilities. It applicable within the field of its intention. The medium, on the other hand, “bites back”. It suggests other uses, may not quite work as we want (...) with a medium, the side-effects may become more important than the original intentions.” (Glanville 1994, p.11) In this chapter, we will discuss parametric design as a design medium which is immeasurable in potency and in its ability to help our thinking - and thus can take a role as a partner in enhancing our creativity. The second thesis is that the serendipity is an early, especially turning point of the very process of evolution. Serendipity is the effect by which one accidentally discovers something fortunate, especially while looking for something else entirely. As Lawrence Block said: “Serendipity. Look for something, find something else, and realize that what you’ve found is more suited to your needs than what you thought you were looking for.” (Parker and Talbott 2008) Traditional CAAD systems limit designers’ creativity by constraining them to work with prototypes provided by the system’s knowledge base. The design is creative if it cannot be composed from the prototypes in the system’s knowledge base. A CAAD system supports creative design if it allows the designer to define novel prototypes to cover these ideas. It is creative if it discovers new prototypes by itself. If we analyse the process and results of
the implementation of parametric methods, we can conclude that most of the obtained forms totally differ from designers’ expectations. (see Figure 2) A subjective/emotional factor has a great effect on the decision-making process in designing. Intuition, unpredictability and no logic are the essence of creativity. In design, often an inappropriate use of tools gives better results than the proper. This way of working with media may surprise and stimulate the designer, offering him or her unforeseen shapes and solutions. The goal is to change creative boundaries of contemporary design tools. In many publications on architectural parametric design we may read the statement that Architecture is simply the collection of principles and operational requirements that are being applied in order to solve design problem. This leads to the conclusion that architectural design is an objective based activity whose primary purpose is to define what is required to provide a solution. If architecture is an objective-based activity, then what
place do emotions and subjective meanings take in this activity? We need the theories and methods for innovation and creation. If we treat parametric design as a medium, we should formulate new parameters for aesthetic design on the conceptual design level. These parameters usually result from subjective assumptions. (see Figure 3) To connect parametric design and creativity, Lee proposed to adopt the concepts of divergent and convergent thinking, two critical factors in the creativity model, to understand parametric design. In parametric design, divergent thinking generates a variety of solutions with the parameters as the “potential answer” to a question, while convergent thinking identifies the most appropriate solution as the “right answer” to a question with rules. (Lee 2014, p. 266)

An interesting approach, in which the subjectively selected parameters and the optimization process were connected, was undertaken at the Faculty of Architecture, Bialystok University of Technology. The goal was to
create space elements which may be used as a mobile partition for dividing the space of an auditorium. The auditorium is a multifunctional space for lectures, consultation, meetings, and exhibitions. Organisation of such different activities simultaneously needs mobile dividing partitions, while until now a large black box was used. Students wanted to make the space more attractive by introducing a new element. An additional function of this element should be a space for leaving information ("a mailbox") and a bench for sitting. Because these elements should contrast with the boxes, it was decided to use curved lines. The first step was to model the black boxes and then draw curves which defined multi-curved volume. In the next step, in the Grasshopper, this volume was divided onto vertical and horizontal parts. Then the algorithm for creation of frame joints was created. As a result, it was possible to generate the optimum contours of the ribs and prepare information for CNC machine. The next stage of optimization was performed after determining the thickness of the particle board plate. After design, the elements were cut and assembled without the need to use any tools. (see Figure 4)
CONCLUSION - IS PARAMETRIC DESIGN A NEW DESIGN PARADIGM?

The Oxford English Dictionary defines the basic meaning of the term paradigm as “a typical example or pattern of something; a pattern or model”. The historian of science Thomas Kuhn in his book The Structure of Scientific Revolutions has defined a scientific paradigm as: “universally recognized scientific achievements that, for a time, provide model problems and solutions for a community of practitioners” (Khun 1996, p.10). On this basis, we may assume that this is the replacement of one methodology over another on the basis of a consensus of the majority. However, in the case of architectural design it seems to be a premature statement. It is difficult to accept the idea of a “majority consensus” in the case of replacing traditional computer-aided design methods by parametric design. Opinions about the architectural revolution caused by parametric methods are exaggerated. The history of architecture shows that designs have always been created in relation to changing factors - climate, technology, usage, environment, culture, and even the character of the building, in other words: they have always been designed parametrically. As was shown in Chapter 1, parametric architecture was the subject of architectural considerations in the 1960s - a few decades before the digital revolution. Nowadays, parametric design is one of many design methods. If we analyse the prevalence of the use of this method, we can note that it is only used in a small number of prestigious design offices and innovative schools of architecture. We can only hope that this method will be applied more widely in the future.

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