



Use of parametric approach for user-oriented development in building design: preliminary investigations

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Abstract

Building design is a highly interdisciplinary research field integrating technological, architectural, structural, social and other aspects. Participatory design, or co-design, already used in other disciplines, is now facilitated by the diffusion of Building Information Modelling which offers greater control of the interdisciplinary aspects in building design. But unlike other disciplines, architecture is characterized by a high number of requirements, partly formalizable, quantifiable and optimizable and partly only intuitive. Furthermore is difficulty to employ a collaborative design framework because designer and end user work on different knowledge levels: one works on satisfying classes of requirements, and the other is unable to abstract his needs and therefore properly formalize requirements or desires. The use of simple parametric models in the pre-design phase, based on algorithms capable of generating geometries dependent on multiple modifiable variables, could overcome this problem.

This paper offers a preliminary investigation on the possibility of integrating bottom-up design aspects by giving parametric models to possible end users and allowing them to explore the design space, identifying preferential outputs and overcoming some of their technical gaps. Working in parametric environments in the pre-design phase opens to the integration of tools such as evolutionary multiobjective optimization algorithms (EMOA). New fitness functions can be defined to bring design closer to the end users' proposed outputs without neglecting performance optimization, which is typical in parametric design. The framework proposed differs from existing "product configurator", used in industrial design, which allows the personalization of aesthetic characteristics. This paper aims at a greater understanding of the end user's will for satisfying them better in the subsequent design phases.

The technological tools currently available to make this framework possible will be analysed, identifying shortcomings and problems, along with methodological implications.

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Keywords

Architectural design; Parametric Architecture; Computational design; Participatory design; Sustainable Architecture

1. Introduction

This paper aims to study a new framework of design development in the architectural field, capable of satisfying the needs of the end user with a participation process based on the use of parametric models. The expected results are indications that the designer can apply in the various design phases. The whole proposed framework is close to the principles of open-source architecture (OSarc) (Ratti, et al., 2011) in particular to the development of designs that are optimized in the terms set by the users themselves. This type of involvement allows users to propose project output and try to engage them in the whole generative logic behind the project.

This new role given to the end user is fundamental, as it underlines the detachment from traditional participation methods based on the involvement in the form of “*questionnaires and working group*” that are often too abstract and could generate *not in my backyard* (NIMBY) attitudes. The proposed framework instead seek to give to the end user a simplification of what is the design process in progress, through the use of modern means of participation. Furthermore, the author is convinced that other than the aimed degree of participation, it is important also the medium used to obtain it (McLuhan, 1964).

The proposed framework can be considered as a platform to involve a plurality of subjects, intercepting the social dimension of sustainable development (United Nations General Assembly, 2015) as well as the objective of Smart Governance (Giffinger, et al., 2007)

2. Parametric approach

The parametric approach to architectural and engineering project is based on linking the final output of a design to generic initial variables, named P_x in Figure 1, through the execution of instructions which can be in the form of algorithms, programming codes, graphs and more. By combining the different states that the parameters can assume, it is possible to associate to a single set of instruction a large number of outputs. These outputs can be analyzed to identify the best solutions comparing fitness function that may concern structural, environmental and economic aspects and much more. The set of possible outputs is called *design space*, which also needs to be designed in the *meta-programming* phase. Is clear the parametric approach to architectural and engineering project concerns more an “attitude of mind” than a set of tools (Whitehead, 2010). With this approach, it is necessary to integrate different disciplines from the earliest design stages for the instruction sets to produce enough defined outputs. This can put the traditional authoritarian model in difficult, and so became necessary to study processes in which the designer also assumes the role of a “*director*” (Sacchi, 2015) who receives input from different subjects. In the proposed framework input from end users are received.

3. Proposed design framework

In the typical parametric approach (Tedeschi, 2014), we design with a loop, dark part of Figure 1, based on parameter variations, output generation following instruction and analysis of the results obtained. In the proposed framework, the author theorises of developing a parallel design loop, based on simplified parameters, instruction and outputs. Through these parallel instruction, the end user can propose design solutions characterized by a high level of geometric definition. This new set of outputs can be analyzed with innovative tools, described in this paper, to orient the design space exploration in the parametric approach.

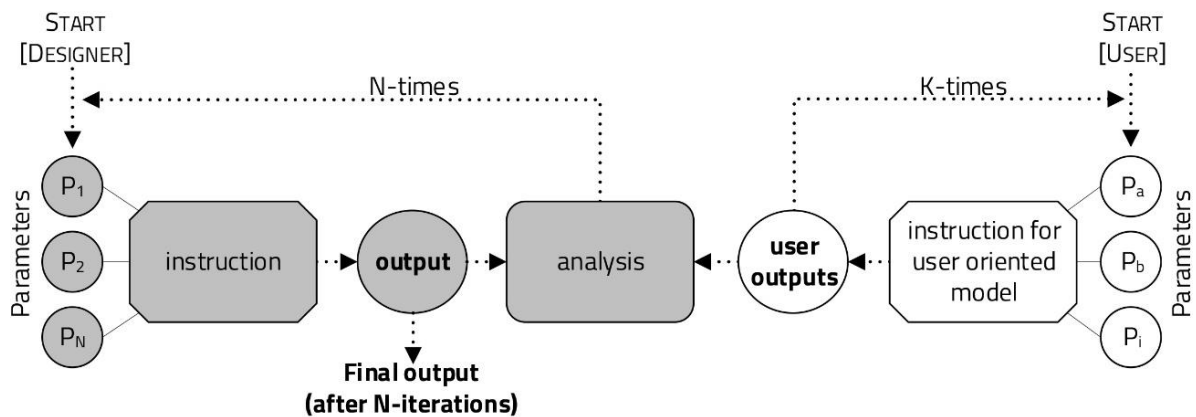


Figure 1 – Proposed design framework. In dark the typical steps of the parametric design process proposed by A. Tedeschi (2014). In white the implementations proposed by the author in which the subjects involved in the participation operate.

3.1. Expectation

The author claims that the proposed framework can improve end user satisfaction by generating positive effects in several fields. First, the end user is pushed to work with a visualization of a real design object. This can bring to the

end user a better understanding on the process that the designer uses to respond to his requirements. Using the widely known schematization in Figure 2 (Alexander, Notes on the synthesis of form, 1972), in the proposed framework the end user would work on the “actual world”, using a mental and diagrammatic project that the designer has already developed: this means that the end user is not able to explore an indefinite design space, but will be able to move in a field of solutions already validated in the *meta-programming* phase. This can allow the end user to overcome some of his technical gaps compared to the designer.

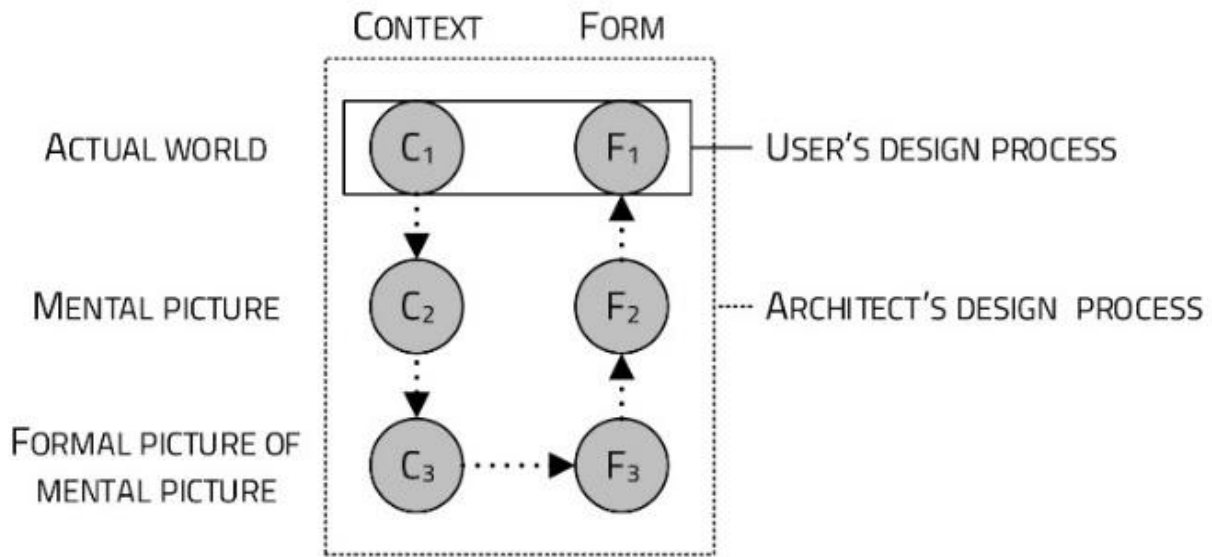


Figure 2 -Role of the designer and end user of the framework proposed in this paper in Alexander's self-conscious design scheme

A second mechanism that the proposed framework can generate is an increased involvement in the participatory process. In the past, attempts have been made to involve the end user in the knowledge not only of the final output but also of the *pattern language* that the designer uses to achieve it (Alexander, Silverstein, Angel, Ishikawa, & Abrams, 1975). Some limits that these experiments have faced are now surmountable thanks to the use of a parametric-based design environment as a platform for implementing the participation process.

A further enabling factor is a greater ability to interpret the generated output thanks to developments in the field of *Big Data Analysis*. Fundamentally, today we can increase the number of users involved in the participatory process until reaching the critical mass necessary for the virtuous open-source process to be established (Ratti, 2014)

Finally, the author believes that the proposed framework can establish among the subjects involved a type of communicative action, where “participants are not orientated primarily to their own success but to the realisation of an agreement which is the condition under which all participants in the interaction may pursue their own plans” (Habermas, 1982) through cooperation.

3.2. Similarities with already proposed frameworks

Thanks to several enabling technologies such as Building Information Modeling (BIM), visual programming, machine learning, concurrent engineering software and more, we can fully realize different framework traced for several years. In particular, it is possible to create a generative design process that responds and reacts to various stimuli (Alexander, Schmidt, Moore Alexander, Hanson, & Mehaffy, 2005). We can design not deterministic output but open schemes in which the designer became and an intermediary (Negroponte, 1975). Finally, the designer can be involved in the process of creating software and procedures capable of triggering new design schemes, as showed in *The Generator* of Cedric Price (The Museum of Modern Art, 2002). Introducing an additional level of participation, allowing actions that modify not only the output but also the instruction to achieve it, we can make the proposed framework capable of exploring, still on a performance basis, a significantly greater design space: this possibility of changing the designed procedure, following the principles of a well-known article (Pask, 1969), would bring the unfolding of the design process closer the functioning of the human thought. However, the implementation of this last point is particularly difficult outside of the academic environment as there are some cultural gaps: end users

typically lack in notions of *algorithm-thinking* necessary to propose viable changes to the instruction set. In other cases, however, it has been recorded that an end user can make changes in a design canvas already validated (Nuijsink, 2008) by working directly in Alexander’s *actual world*.

3.3. Tools for implementation

To work with the proposed framework, we must set up an environment composed of a user-friendly visual editor capable of modifying the states of parameters and a real-time 3D visualization of the proposed output. The entire generative instructions could be given to the end user if the possibility of activating a modification process on it exist. The effectiveness of the proposed framework depends on the correct choice of the parameters given to the end user. They must be in a limited number but capable of significantly modifying the final outputs. Design parameters that have strong impacts on social aspects such as the average size of an apartment or the characteristics of its functional layout could be given to the end user.

However, considering some limitations on the software currently available to designers, some parametric procedure could not be repeatable on an open-source platform. This is the case, for example, for procedures based on physical form-finding, which could require the use of codes and software under copyright. Implementations with these form-finding may require an additional interdisciplinary effort to overcome intellectual property problems.

Software suites able to manage the proposed framework are partially existing and there can be a transfer of knowledge from the *product configurators*, widely used in industrial design. A typical suite used in the parametric approach consists of the software Rhinoceros, Grasshopper and related plugins. We can implement the technology proposed by Shapediver on a cloud basis to move the computational effort from the end user to a server and make possible to explore the design space on multiple types of device (Shape Diver, 2020). Being able to receive proposals not only from computers but also from smartphone and tablets would significantly enlarge the people reachable by the proposed framework.

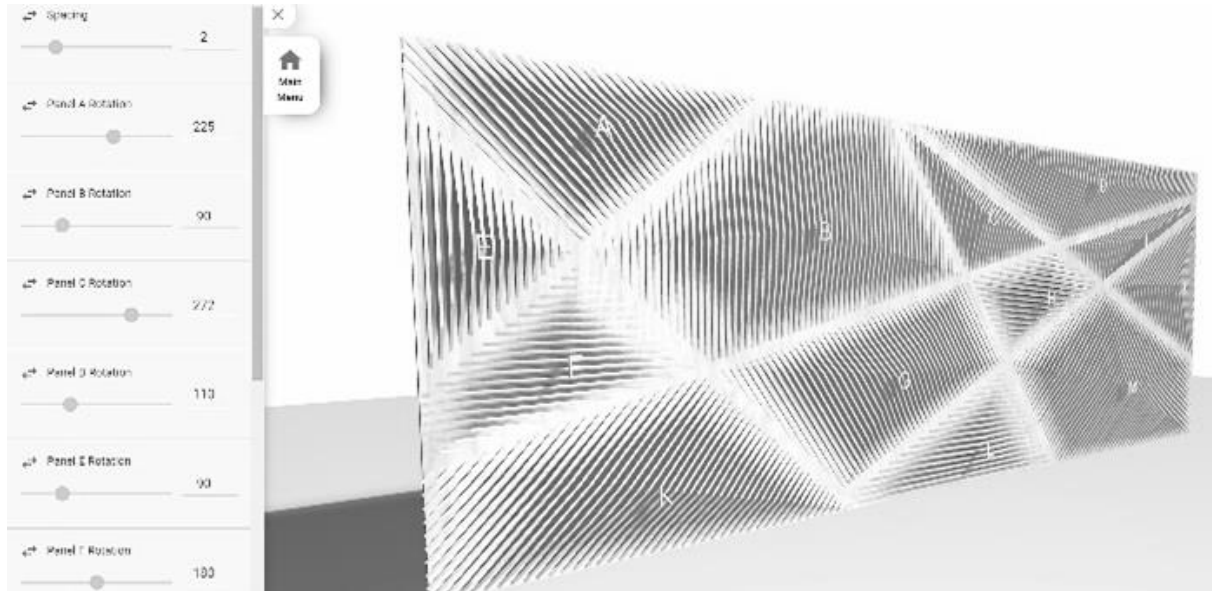


Figure 3 A product configurator by MAK STUDIO, implemented on the ShapeDiver Tecnology. On the left we can see the visual editor and on the right the real time 3d visualization. Available on <https://mystuff.makecoolstuff.us>

3.4. Tools for analyzing the received outputs

It is necessary to transform the collected data into design indications, both qualitative and quantitative. The parametric approach can be used with different levels optimization: for the proposed framework, it is necessary to use tools which can identify performing solution while leaving a consistent autonomy to the designer. The chosen tools depends on how the design space is explored: the “N-Times” step in Figure 1 could be done with an iterative process or could be automatized with the use of EMOA. In this paper, the implementation of “heatmap” and “cluster data analysis” for obtaining useful design indications will be briefly described.

Heatmaps are one of the most popular methods for visualizing complex data structure on a matrix basis (Wilkinson & Friendly, 2008). Data that can be extracted from heatmaps and may be useful for the proposed framework concerns how an end user explores the design space. We can collect and visualize the times in which they linger in the modification of a parameter. This information can be used to hierarchize the parameters on which the participation process is based, to better direct the design effort towards what, consciously or unconsciously, causes changes in the end user's perceived satisfaction. These tools are today widely used in the design of User Interface (UI) because of their economic implementation and agile consultation. (Hergul, 2020)

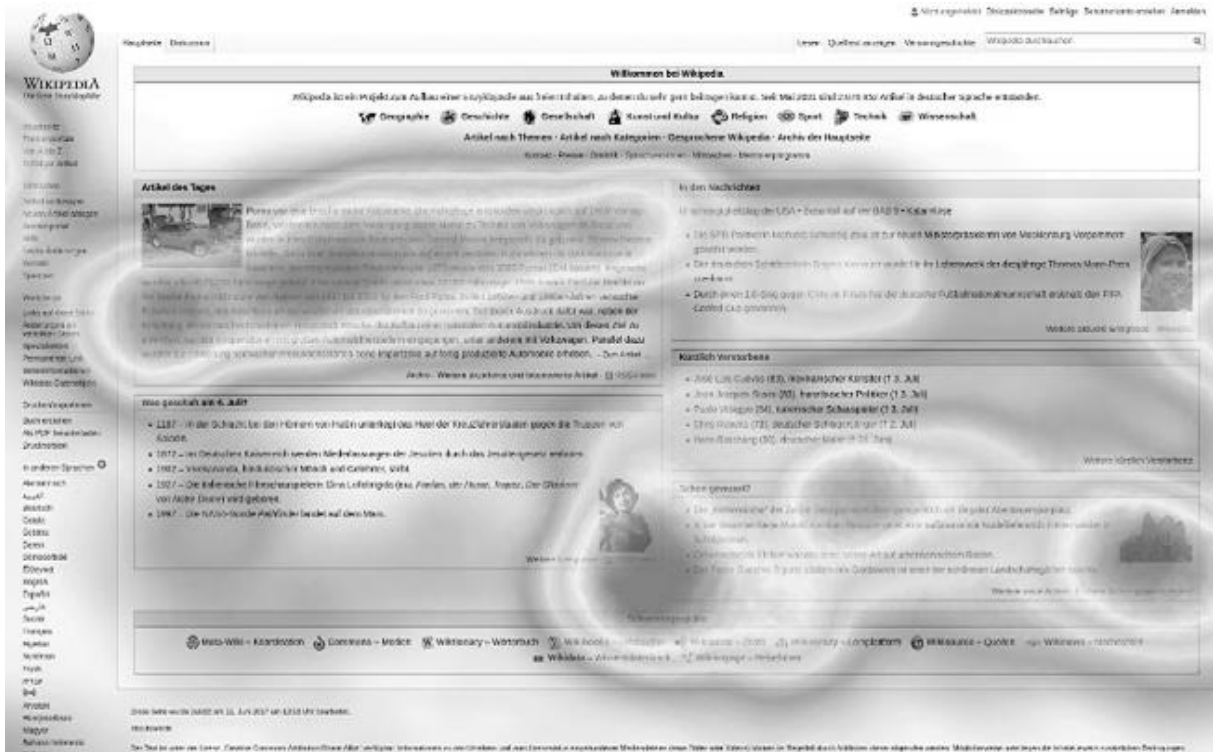


Figure 4 (a) Use of heatmap in UI, source: wikipedia.com

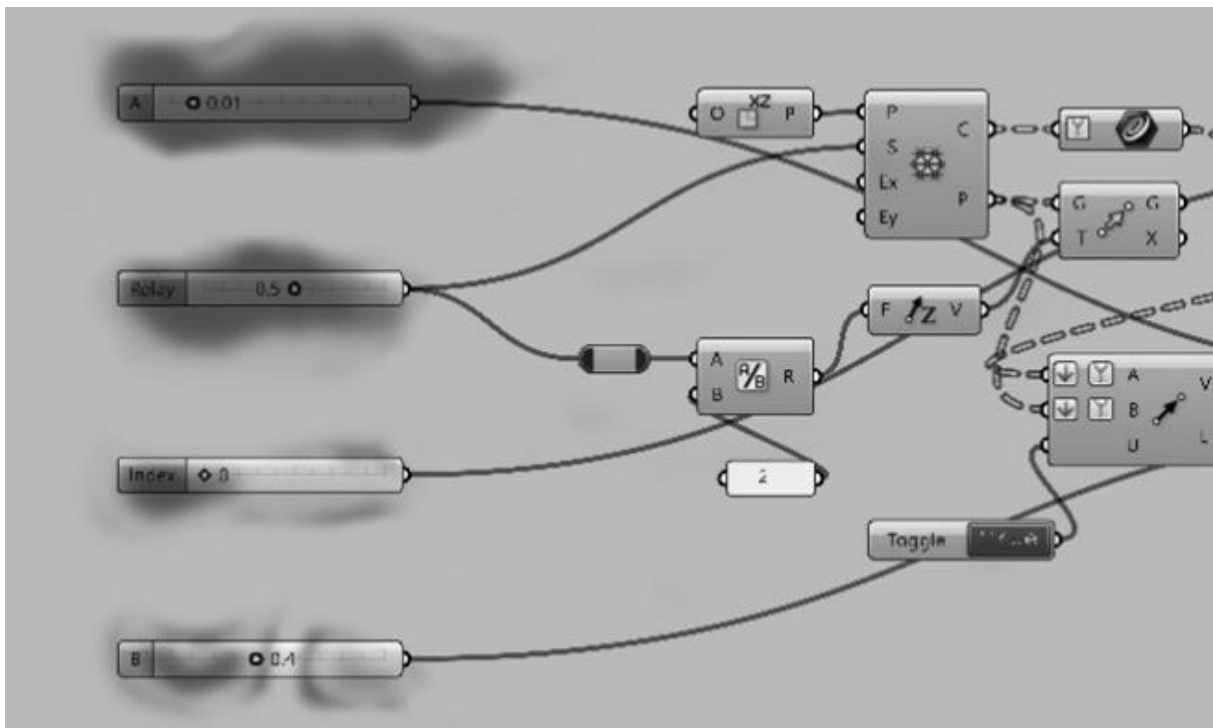


Figure 4 (b) Qualitative frequency of parameter modification

Cluster analysis, or clustering, is a useful tool for identifying, within a large amount of data, homogeneous groups that share similar characteristics. In the architectural field, they have been used to optimize the production and construction of building elements. This is the case of the executive design of the Soumaya Museum's façade, Figure 5, in which clustering was used to divide the surface into families of homogeneous panels to reduce its cost (Ghery Technologies, 2013). The author identifies that this tools, with reference to the k-means algorithms (Mitra, 2019), can be used in both qualitative and quantitative terms in the proposed framework. The cluster data analysis done with k-means algorithm is used for obtaining quantitative indications (Garbade, 2018) because fitness function that reward project outputs closer to the proposal of homogeneous groups of end users can be implemented.



Figure 5 – Museo Soumaya – Source: Diego Delso, delso.photo

4. Conclusions

The proposed framework can be pursued, as has been shown into the implementation and analyzing paragraphs, with more rigorous or more qualitative approaches. The transformation of external inputs and proposal into action and design strategies shows how a framework can have an important role in the quality of architecture (Purini, 2018). The author believes that the proposed framework does not influence the formal themes of architecture, as they can be predetermined by working consciously on the explorable design space in the *meta-programming* phase. Rather, these external inputs push to work on a performative level, transforming an end user's proposal into a requirements to be satisfied without distorting the system and design principles already identified by the designer.

It is necessary to recognize that including participatory aspects in the architectural design requires, to some extent, a greater effort than with the authoritarian model. Additional skills are required to the designer because it is necessary to be more receptive and agile throughout the whole participatory process that must not be reduced to transcribing what an end user desires, but it is a dialectical moment between a multiplicity of subjects. (De Carlo & Bunčuga, 2000)

Finally, it is necessary to recognize that, thanks to the development in the field of data analysis, ethical risk may arise in the use of the proposed framework because the shown participatory tools can be used for a false democratic justification of already taken design decisions. The author acknowledges that these are risks common to most participatory process.

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