Notes on the development of a parametric design process for a brise soleil system

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ABSTRACT:
The process of adopting digital simulation and design tools into an existing procedural framework is tedious in that it requires a significant investment by the users. Software manufactures aim to create interfaces that can easily be understood and put into practice. That being said, other factors, such as the lack of climatic data, deter the quick absorption into professional practice. In a country such as Colombia, which is in a zone near the equator and is characterized by drastic differences in topography, the preprogrammed climatic data is insufficient. Even when figures are provided or manually configured, parallel simulations between various software packages reveal significant discrepancies in terms of estimated performance. Wary of this, yet optimistic of the potential of parametric modeling, the authors have developed and implemented a methodological procedure which first articulates the design problem, then develops the parametric model and lastly applies this model. Upon reviewing more than a hundred variations, one configuration was selected as the highest performer. A prototype has been built and is currently being monitored by other researchers with the aim of rectifying the divergence in computed data by various software packages with real numbers. This paper will explain how the parametric design process was developed and the methodology employed in search of an efficient and effective brise soleil system.

KEYWORDS:
Parametric Design; Eco-Logical Design Process; Computer Aided Architectural Design; and Brise Soleil
INTRODUCTION: CONSIDERING COMPUTER ARCHITECTURE AND COMPUTATION IN ARCHITECTURE

Tracing the history of computer architecture takes us back several hundred years to the developments of people, such as: Müller, Babbage, Menabrea, Byron and Clement. The first documentation of computer architecture is believed to be found in the communication between Charles Babbage and Ada Lovelace when they were describing the Analytical Engine. This magnificent mechanical device was derived from the mind of Babbage and followed upon the development of the Difference Engine as it provided more general design that could complete arithmetic operations. The machine integrated concepts, such as; branching, memory, looping and was computationally universal or Turing-complete. Only small portions of the invention were built by Babbage and his engineer Joseph Clement, however, he knew he was onto something incredible. In his text, Passages from the Life of a Philosopher, he posits, “As soon as an Analytical Engine exists, it will necessarily guide the future course of the science. Whenever any result is sought by its aid, the question will then arise—By what course of calculation can these results be arrived at by the machine in the shortest time?” (Babbage 1864)

The issue of speed continued to inspire other inventors to continue the development of computer architecture. A hundred years after Babbage described the Analytical Engine, Alan Turing laid the foundation for modern computing through his Turing machine which has been identified as the blueprint of electronic digital computer. The ABC, ENIAC, Z3 and Colossus were all important achievements as they are the evidence of the ground that was broken in computational development seventy years ago. These machines were gigantic calculators that proved much more efficient in mathematical calculations than the human mind. Programma 101 and the Hewlett Packard 9000 series were introduced in the mid-sixties which led to programmable desktop computers in the 1970’s. The exciting 1968 presentation of Douglas Engelbart, known as the ‘mother of all demos’, foretold of a new future reliant on computational technology which sparked the imagination of many. From that era on, the evolution of architectural computing has been of great interest to society at large. A continual progression that has allowed for exponential growth in power (speed) and drastic decreases in physical dimensions has forever altered the lives of billions. To what effect has computer architecture affected the architecture of design and construction?

When considering computation in architecture, Nicholas Negroponte has referred to processes of ‘absorption’ and ‘adaptation’ as natural processes that occur when new technology is introduced. Despite a relatively slow process of ‘absorption’ into the architectural practice which has spanned the past three decades, continual improvements in hardware and computing power paired with the rapid evolution in software have created a favorable condition for the ‘adaptation’ of computing into the practice of architecture.

This has generated interest and inquiry by both practitioners and scholars in the field of architecture. The architectural discipline both in academics and practice, has struggled with the way to which computation should be utilized as a tool in design processes. Aware of the potential of computing,
a digital discourse in architecture developed around ideas of expediency, a representationalist use of
digital tools. However, what has surfaced in recent years is a growing interest in the possibility of using
computation and parametric tools which not only aid tradition activities, but can facilitate an iterative
systems approach to design that supersedes the original notions of Computer Aided Architectural
Design (CAAD). (Bermudez and Klinger 2003)

1. Towards an Eco-Logic in Parametric Design

"Constructing narratives of utility provides an escape from tautological
parametric solipsism without forsaking formalism by providing an
instrumentality of form, which could include pragmatic performance,
the visceral, as well as the intellectual, discursive, or meaningful.”
(Meredith, 2008, 8.)

One particular way that iterative systems approaches are being approached is through the notion of
parametric design. Advances in software paired with certain stylistic tendencies have received significant
attention in recent years, though the concept and terminology is nothing new. This notion was an
essential proposition in the development of for Ivan Sutherland’s PhD research for Sketchpad published
in 1963. Numerous architectural software has integrated limited parametric functionality ever since,
however; the explicit determination of designers to incorporate three dimensional parametric design
thinking in their work flow is a contemporary preoccupation.

As animation software such as Maya has been adopted by young architects and interfaces for scripting
and programming have been further developed and become more instinctive (as seen in the Grasshopper
plug-in for Rhinoceros and Bentley’s Generative Components), a solidified movement of ‘parametric
design’ with an organic aesthetic has emerged. Intending to solidify and increase coherence for this
new movement, Patrik Schumacher states, “Contemporary avant-garde architecture is addressing the
demand for an increased level of articulated complexity by means of retooling its methods on the
basis of parametric design systems. The contemporary architectural style that has achieved pervasive
hegemony within the contemporary architectural avant-garde can be best understood as a research
programme based upon the parametric paradigm.” (Schumacher, 2008, 1.) After establishing the
criteria and describing the characteristics of the evolving style which he calls Parametricism in a
2008 manifesto, Schumacher’s ambitious agenda has involved an attempt to establish the validity of
Parametric Design as an important movement within the history of architecture. Indeed, there has
been significant attention towards computational design in architecture and much of it has been
relegated to the field of aesthetics and high levels of interest in the generation and articulation of
complex geometric configurations. Yet, despite these efforts to substantiate a new style in architecture,
there is a natural denigration of this proposal when the wastefulness of the lavish exuberant aesthetic
proposals is demonstrated.

This area of interest in the architectural discourse has the potential, however, to be of greater value if it
is capable of expanding upon the current scope of design as a research program and aesthetic theory to
an program that embraces other criteria, such as; environment and performance.

As indicated in the title of this section, the authors support the use of eco-logics in the design process
and in particular the development of a parametric design methodology. A lax use of English vocabulary
has often used the term ‘ecological’ as a synonym of ‘sustainable’, yet the root of ‘eco’ is the Greek ‘oikos’
which is a word that refers to a place of dwelling. The word ‘ecology’ was clearly defined as a division
of science that studies the relationship of living things with the environment they inhabit. “It is in the
logic of interaction among components of an environment that function as one whole ecological unit.
It is in the logic of interaction among components and their overall system dynamics that the focus of
this science resides.” (Catala, 2010, 89.)
Contemporary architectural design problems involve the resolution of variables that require computation beyond human mental capabilities. Furthermore, undertaking an eco-logical architectural design process is even more complex in that it goes beyond isolated architectonic objects and involves the study of relationships and speculation of new conditions to be generated. This is an iterative process that mandates the consideration of an extraordinary amount of components through modeling, simulation of performance, and analysis. Parametric design caters to this process in that it requires the articulation of relationships between components and creates a framework that allows the designer the flexibility to evolve design proposals.

In academia in an undergraduate program in a Colombian institution, the authors are involved in teaching and researching about facade systems. In these activities, there is an affinity to understanding the local environment and the idea of integrating computing into the design process. An effort has been made to develop an eco-logical parametric design methodology which has served as part of a larger research project called Eco-envolventes. Stemming from an interest in developing environmental design strategies for local climatic situations, this project is attempting to fill a gap in literature that does not provide comprehensive information for zones near the equator. The activities of this project include modeling, simulation and comparative analysis with the performance of physical prototypes located in hot and humid tropical climates.

2. Eco-envolventes: A case-study of environmental performance prioritization

“Eco-envolventes” is an on-going research project that looks to explore and find appropriate building envelope solutions for tropical humid climates involving passive control of thermal gains on their surfaces, thus allowing for better internal conditions and thermal comfort without the use of thermal machines. Environmental principles, design, and technological aspects are specifically defined based on the peculiar conditions (geo-climatic, technological, of biodiversity and economic) present in the Colombian low altitude regions, marked by constant high temperatures. Thermal and CFD simulations orient the process of experimental verification in a permanent laboratory counting on industry partnerships and available know-how. This paper presents only a small part of the project, that concerning the design component, involving the proposal of a parametric design structure to apply and support the general research findings (Velasco, 2012).

2.1 Design determinants

The design of building envelopes is probably the epitome of architectural design as it includes and blends technological, functional and design factors, reminding us of the classic trilogy firmitas, utilitas, venustas proposed by Vitruvius, i.e. the envelope as any architectural structure should be robust, functional and beautiful. An interesting recent proposal (Schittich 2006), however, proposes the inclusion of a fourth aspect in the design of enclosures: ecology, involving the sum of the energy consumed in the construction and use of the envelope as design factor.
An inter-relational scheme of this type (Figure 2) very well represents the nature of the problem, but is not particularly useful to define the relationships among specific design parameters, which is why we propose a new model where the design problem is at its center (Figure 3), in this case, including formal qualities within it. We could then point out three major aspects that should guide any design solution for building envelopes, the first would have to do with the functional requirements of the envelope, i.e., the envelope as providing comfort conditions inside the building. The second fundamental aspect would have to do with the fulfillment of such functional requirements in terms of the technological and economic resources available, and finally, the third would be the environmental aspect, which would involve two pre-conditions for any proposed design: it's suitability to geo-climatic conditions and a low environmental impact for particular environmental conditions.

2.2 The scope of the research project

Based on the requirements of a particular region, the Eco-Envolventes project is one example which one of the authors has created an integrated and iterative approach that defines, analyzes and considers a set of parameters which guide the development of a brise soleil system to serve as the building skin. This is currently a work-in-progress, so this article does not put forward the results as authoritative, but intends to present the development hitherto. Within this section of the article, the methodology used in the generation of the facade system will be explained. Three stages have been identified which include; 1) Formulation of the problem, 2) Development of a parametric model, and 3) The application of this model.
2.3 Geographic location and climatic data

The climatic, ecological, and economic conditions found in a typical developing world tropical location are exemplified by the town of Girardot in Colombia, where the climate is common to great part of the Colombian territory. Located to 292 m asl, Latitude 4,16º N and Longitude 74,49º W, has an average temperature of 27,4º C (minimum: 24,0º C, maximum: 32,3 º C), a relative average humidity of 80%, 821 mm of precipitations with raining 76 days and 213 hours/month of solar brightness. The peaks of maximum temperatures reach to 40,0º C, whereas the minimum fall to 21,0 º C. Generally, in 273 days/year (74,8%) temperature rises above 32 º C. With an annual average 4,575kWh/m2/day solar radiation, is evident that the sun is an agent who takes part strongly in the thermal economy of the envelopes contributing in 4º C (in average) up to 11º C to the air temperature.

![Figure 4 - Psychometric Chart for Giradot and and forecast rates of comfort with the use of selected passive strategies.](Author 2011)

2.4 Formulation of the problem

The first stage is dedicated to the formulation of the problem which involved a study of issues pertinent to state of the art facade design through a comprehensive review of special facade designs and existing literature. The literature review prior to the development of this research has shown that most of the publications on the subject tend to classify envelope systems based on a single parameter, the type of material used in the solution, demonstrating such categorization through case studies. There is a scarcity of information that documents methodical analysis based on the configuration of layers or integrated systems in the envelope system. The existing literature that complies with the scope of integrated systems is generally related to specialized double skin glass facade systems typical of solutions for structures that are situated in high-latitude climates. (Knaack 2007, 2008) Several three-dimensional digital models were created and analyzed (simulations in Ecotect and Design Builder were conducted) in parallel to gain insight and provide preliminary data about the performance of particular solutions in hot and humid climates.

The analysis of the information in the literature review and preliminary simulations resulted in the identification of three types of major determinants necessary to understand in the creation of any type of building proposal, these factors include; functional, technological and environmental.

Functional factors relate to the way in which the skin of the building provides human comfort zones inside working as a protective barrier. These factors determine the degree of comfort that the system defines to the covered spaces. Four main criteria related to function have been identified: thermal control, light transmission, ventilation and soundproofing.

Technological factors deal with the means and technologies used to know about what, and how the proposed building envelope is built. We have identified four factors that determine how the performance of the proposed design may come to be evaluated and control the degree of articulation
of the proposal in terms of technology and construction: structural capacity, construction efficiency, safety and durability, and costs and maintenance.

Environmental factors relate to the global physical environment within which to locate the possible envelope. This includes biodiversity -native plants and / or other living species- and energy issues. These factors define the impact of the system on the natural environment that surrounds it at local and global scales, which may imply requirements in terms of various subjects such as embedded energy, absorbed-emitted thermal energy, support for local biodiversity and production of O2.

A series of factors that could be assimilated as groups of system requirements is included in each of these categories. These groups were classified into specific requirements having the potential to be evaluated, and thus incorporated as types of analysis and as feedback for the generated proposals. The first emphasis of the Eco-Envolventes project is on the articulation of these systems and subsequently on the architectonic designs which are created through the enmeshing of these defining factors. In this study, design is to be understood as the integrator.

### 2.5 Design parameters

Three groups of design parameters that were to be implemented as design variables were then defined for the generation of design possibilities: general parameters, structural parameters and cladding parameters. These groups of design variables formed a structure from which we were able to produce a set of configurational possibilities which were subsequently tested by different types of analysis relative to the original determining factors. (See Table 1)

![Diagram of design parameters and analysis types](image)

**Table 1 - Definition and relationship between; Determining Factors, Design Parameters and Types of Analysis. (Author 2012)**

According to the general configuration rules set out above, the design parameters proposed can be divided into three groups: the first relates to the general definition of the building envelope, the second parameter corresponds to the supporting structure, and the third parameter considers the cladding. We have identified 12 parameters to define the design and characterization of architectural envelopes for tropical climates: location, relative position, surface morphology, scale, structural configuration, grid type, sections of structural work, joints and anchors, structural material, type of closure, permeability, and materials for closure and plant support. The figure above shows the relationship between the
determinants and proposed design parameters for this research, defined in three main categories: general, structure and cladding.

2.6 IMPLEMENTATION OF THE PARAMETRIC STRUCTURE

A parametric structure is synonym of an inter-relational organization, where the parts are connected within a coordinated system, thus implying the possibility of changing parts and recreating new settings automatically. (Woodbury, 2010, 11.) Thus the parts of our model, the way and the ranges by which they change, and the general rules of the system must be defined. These parts have been called “design parameters” which generally involve particular configurable types (variation fields), where internal definitions (variables) can have differential values of specified ranges (values). The following explains the general rules, the definition of the parametric structure, allowing programming using digital tools.

2.7 GENERAL RULES OF THE SYSTEM

General configuration rules are given by previous analysis of research conducted within the frame, where passive strategies were explored in warm moist air to achieve reasonable levels of comfort within the covered building. As shown through pre-basic analysis, the most important strategies were ventilation, thermal inertia, solar protection and night cooling.

The proposed research involves the use of double-layer systems that may allow selectively indoor and cross ventilation. Thus, seeking the application of these promising strategies and guided by the requirements proposed as determinant factors, we have considered only a limited number of design parameters. These general parameters of design are related to the general definition of the envelope, its structure and enclosure: the proposed configurations would be constituted by double-enclosed particular combinations using the interior void as the cavity for the structure. This allows for the possibility of permeability, the use of vegetation, and the use of recycled or renewable materials. The panels will be constructed from prefabricated components which will also allow for easy assembly and disassembly.

<table>
<thead>
<tr>
<th>DESIGN PARAMETERS</th>
<th>VARIABLE FIELDS</th>
<th>VARIABLE INSTANCES AND RANGE VALUES</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td></td>
<td>Orientation x, Orientation y, Edge curve geometry, Opposite frequency</td>
</tr>
<tr>
<td>Relative positioning</td>
<td></td>
<td>Orientation x, Orientation y, Edge curve geometry, Opposite frequency</td>
</tr>
<tr>
<td>Surface morphology and size</td>
<td></td>
<td>Orientation x, Orientation y, Edge curve geometry, Opposite frequency</td>
</tr>
<tr>
<td>Latent type</td>
<td>Uniform, Non-uniform</td>
<td>Orientation x, Orientation y, Edge curve geometry, Opposite frequency</td>
</tr>
<tr>
<td>3D configuration</td>
<td>2 directions, 3 directions</td>
<td>Orientation x, Orientation y, Edge curve geometry, Opposite frequency</td>
</tr>
<tr>
<td>Structural sections</td>
<td>Hollow profile, Solid profile, Flanged</td>
<td>Orientation x, Orientation y, Edge curve geometry, Opposite frequency</td>
</tr>
<tr>
<td>Material type</td>
<td>Mechanical, Chemical</td>
<td>Orientation x, Orientation y, Edge curve geometry, Opposite frequency</td>
</tr>
<tr>
<td>Cladding</td>
<td></td>
<td>Orientation x, Orientation y, Edge curve geometry, Opposite frequency</td>
</tr>
<tr>
<td>Surface configuration</td>
<td></td>
<td>Orientation x, Orientation y, Edge curve geometry, Opposite frequency</td>
</tr>
<tr>
<td>Permeability</td>
<td></td>
<td>Orientation x, Orientation y, Edge curve geometry, Opposite frequency</td>
</tr>
<tr>
<td>Material types</td>
<td></td>
<td>Orientation x, Orientation y, Edge curve geometry, Opposite frequency</td>
</tr>
</tbody>
</table>

Table 2: Definition of structure and design parameters. The dark names indicate a direct relationship to geometrical, thus to be included in the 3d parametric model definition. (Author 2012)
2.8 Design Generation

Following the above mentioned structure where the technological, environmental and functional factors that demarcate our particular space for physical configurations were integrated, we further defined the variable fields of seven design parameters whose functional and technological behavior could be importantly influenced by their geometrical configurations. As discussed above, the design parameters were constrained into three groups, the first corresponding to the general conditions, the second for the structure, and the third defining the cladding, this to be subdivided into external and internal.

The diagram above [Table 2] shows a further description of the proposed design parameters for this research, the geometrically related design parameters (in black) can be directly controlled from three-dimensional parametric definitions built on Rhinoceros-running Grasshopper, producing specific digital models to be evaluated using structural and environmental software packages. Material and functional parameters were to be defined using an Excel based spreadsheet, were options are linked to specific pre-determined values and computed with the incoming data resulting from evaluations of the three-dimensional model. Here we shall briefly describe each of the general fields.

2.9 First Application and Performance Simulations

The designs were analyzed in terms of their performance as climatic barriers and providers of comfort. In order to run the simulations, temperature, lighting and ventilation evaluations were carried out using the software packages Ecotect and DesignBuilder. Using the material assumptions found, the parametric model was used to “fine tune” the best geometrical attributes to design a particular case, being that the west facing facade of the existing university buildings in Girardot. Thermal and CFD simulations were carried out to evaluate the original conditions, and to be compared with the performance of 60 design configurations given by the proposed parametric definition. (Table 2)
Figure 6 - The image on the left is a visualization and simulations of the internal temperature of classrooms in an existing building at the Universidad Piloto in Girardot. The simulation on the right shows the results with the proposed facade (modular ceramic and interior brick wall) which achieves a decrease in internal temperatures close to 6º C (10º F).
(Author 2012. Simulations by Sarah Luciani)

2.10 Re-defining the problem: Dynamic brise-soleil elements

The parametric structure described above set the approach to the problem of designing building envelopes for hot and humid climates by providing multi-criteria performance data regarding generic solutions. However, such a general and all-encompassing scheme would imply far too many possibilities to analyze, which would impede a profound examination of each specific solution. Following that, in accordance with the iterative methodology proposed here, and based on the existing data, the design problem was reduced to that of brise-soleil geometric configurations (outer layer), even if made more complex by adding a time parameter to it.

Figure 7- Two different configurations for dynamic elements
Rethinking Traditions and Envisioning the Future in Architecture Through the Use of Digital Technologies

Figure 8 - Details and thermal simulations of the above configurations

Thermal comfort was now solely dependent on solar gains, but the protecting elements would change in time by tracking the solar trajectory specific to a particular site. In this way, maximum protection would be provided, whilst allowing ventilation when required. Continuing with the same design application, i.e. the university building in Girardot, various configurations were tested and a particular solution was selected to build a pre-prototype and test on site.

Conclusion

Being analytical has been an important feature from the very beginning of computer architecture. It should also be a core part of the contemporary computational architectural design process. This paper has illustrated that employing an eco-logical parametric design process has great potential in resolving the complexities in the field of architecture. After making this claim, the article continued by using the case study of Eco-envolventes to demonstrate how the formulation, development and implementation of a parametric design methodology has been employed to develop a brise soleil facade system that addresses the specific climatic situation in a Colombian city near the Equator. As design processes, such as; parametric modeling, building information modeling (BIM) and architectural visualization software are utilized, architects are encouraged to look beyond the surface and incorporate feedback from the physical and cultural contexts as parameters to design innovatively.

Architectural design is discursive and even though this document reveals an ongoing project, there are already results that can guide designers towards informed solutions for projects of similar characteristics. The parametric design process is one that relies on the visualization of models not only to understand form, but also performance. The culmination of research to date will not provide a defined equation which explicitly states the manner to which an ecological digital design process should be approached. Rather, what is illustrated is how we have gone about using parametric modeling in our exploration of designing and developing a brise soleil facade system that seeks a high level of performance. This study presents a methodology that can aid in the construction of new and more efficient approaches to design. These proposals are digitally driven and strive to achieve maximum performance through the agency
of an eco-logical parametric modeling. The visibility of the results are evidence that not only does the parametric design solution for the brise soleil system mitigate the negative environmental impacts of building, but is also able to achieve levels of internal comfort highly desired by the inhabitants and produce constructive relationships between the inhabitants and their dwelling.

ENDNOTES

1Eco-envolventes is a multi-disciplinary research project developed at the Universidad Piloto de Colombia, developed by Claudio Varini (Main Researcher), Rodrigo Velasco (Parametric definitions) Tomás Bolaños (Biologist), Eduardo Rocha (Architect and material expert), Andrés Moscoso (Architect), Camilo Contreras (Structural Engineer), Paulo Romero (Industrial Designer and LCA expert) and Sara Luciani (Digital simulations).

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