From Dynamic Visualization to Designing Sustainable Architecture

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Abstract. The efficiency in the use of energy is a subject that transcends our current affairs, it is one of the needs and demands of contemporary times. As designers it is our responsibility to devise resources that pose our position in the face of the challenges that arise in the era of new technologies. The objective of this study was to design parametric processes that allow us to determine the best locations, from the energy efficiency of the weather factors, for different devices and devices through digital simulations concerning the real environment. Experiences were carried out from passive and active energy optimization such as shadow study, solar radiation and renewable energy implementation. Being an investigation for project purposes, three types of actions were carried out: analyze, project and evaluate. Finally, the research allowed us to appreciate the potential of emerging techniques and how these dynamic systems can generate a family of solutions to a certain problem such as energy efficiency. The visual interface proposed by the research allows simple visualization and orders a lot of complex information. As they are parameterized studies from the geographical location, they can be repeated quickly at any latitude, saving time and expanding the project possibilities based on weather conditions.

Keywords: Parametric architecture · Sustainable design · Energy efficiency · Parametric graphics

1 Introduction

Energy efficiency is not only a topical issue, it is one of the needs of our time, which requires rethinking our attitude towards non-renewable energy sources and the development of new technologies. As architects of this era, it is our professional duty to seek solutions to modern space problems that promote sustainable development.

If we intend to train as architects willing to face current energy efficiency problems, we must consider that the complexity of these conflicts far exceeds the traditional technical training of the profession. For this reason, requires us both to understand and study different fields of knowledge and to work as a team with other disciplines.

Assuming this position, we must consider that the complexity of these problems transcends our traditional training and, for this reason, we are required to educate ourselves in different fields of knowledge, such as to contemplate the possibilities of interdisciplinary work with actors from other areas.

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Our research aims to design a system that, based on parametric logic, helps the designer to develop spatial envelopes that, in addition to protecting the interior space to save energy in conditioning, generate storable and usable energy. They will be formed from repeatable and attachable modules.

2 Methodology

2.1 Methodological Stages

As it is project research, three types of actions are carried out: analyze/diagnose, plan/design, and evaluate/reflect. In turn, as the research process is continuous, open and flexible, it proposes a dialectic between the activities, which do not develop linearly, but through a spiral of a pro-feeding nature that generates a constant movement between thinking and practices, that is, all the activities and moments of the process are related and constitute a source of data.

The analysis and recognition phase establishes the definition of the study problem; the analysis of its effects on subjects and practices, and its interrelation with other problems; the description of contextual constraints; and the recognition of available knowledge and instruments to study alternative solutions. The analysis of the cases culminates with a reflexive diagnosis, outlining a relational scheme that links problems, conditions, instruments and possibilities, and is expressed in anticipations of meaning or particular hypotheses, which propose actions or overcoming proposals.

The second stage includes different activities (such as design, planning and project), which are interdependent: planning design, action and observation strategies; relevant modes and evaluation techniques; and relevant data construction instruments, to the object of study. In addition, these processes require the design of interfaces and devices that integrate sensors, with the aim of surveying and recording information on environmental conditions, and then producing different types of actions, as necessary.

The third stage of the methodology consists in exploring relationships between the project disciplines and the technological instruments and devices recently incorporated into the culture, in this way, new relationships can arise, applicable to research from a multidisciplinary perspective.

2.2 Parametric Design

The main instrument of this investigation is the parametric design. All processes are developed through the logic of the parametric design and are developed in software with "Rhinoceros" with the "Grasshopper" plugin.

Rhinoceros is a 3D modelling software. Grasshopper is a plug-in which Works inside Rhinoceros and it is usefully to parametrized algorisms and values. Together, work as one software and allows you to connect different components that contain programming code segments inside. In this way, each component has inputs and outputs generating different types of data which, in turn, are displayed in 3D on rhinoceros.

The parametric design constitutes an alternative to the linear design model of typical CAD software since it allows all the components of the design to be related and used as modifiable variables in real-time. The parametric design allows the generation of geometries from the definition of a family of initial parameters and the programming of the formal relationships that they keep between them [1].

The complexity of programming is simplified through a simple graphical interface. This allows you to connect components that contain code lines and modify the geometry that is being developed (Fig. 1) [2].

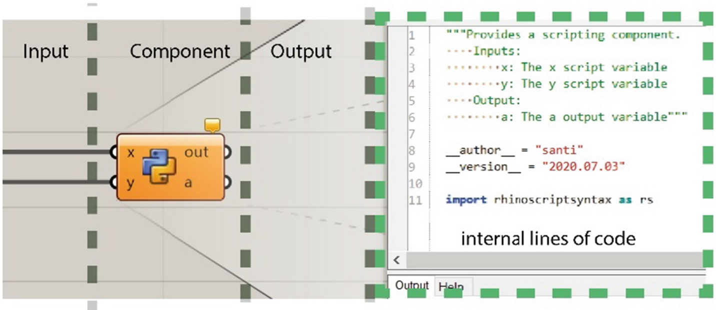

Fig. 1. Each component has data inputs and outputs. Once inside, the information is modified according to the component code.

3 The Project

3.1 Location

A study sector was established based on the characteristics of a medium-scale city. The region used as a study area is the city of Santa Fe (Argentina) and its surroundings, delimiting a series of weather conditions.

The source of meteorological data was the Santa Fe Metropolitan Airport (AMSF), which has had sensing and measuring equipment for years. In turn, the data was entered into Grasshopper through the open-source plug-in "Lady Bug + Honey Bee" which are extensions available for Grasshopper and which are used to analyze data to obtain accurate results and map them in a simple way.

The first thing that was done was a verification between the data obtained from the AMSF and the available national and international sources that openly present their data. These sources were: The National Climate Data System (SNDC) and by the National Aeronautics and Space Administration (NASA) Solar Data Department dependent on the United States, for more information consult the corresponding websites. Comparison of the information determined that the AMSF data is reliable, because the information obtained corresponds to the verifying sources.

In order to use the plugins of the Grasshopper plugin, it was necessary to use other software that allow data collection and display them in a decrypted way, these programs are Open Studio, Energy Plus, Daysim, Radiance, among others. Through the

Energy Plus software, files can be opened in .EPW (Energy Plus Weather Data File) format, a format developed by the U.S. Department of Energy, which stores various weather data. In turn, the climate.onebuilding.org website allows free access to files in . EPW format where data is collected from sources that have certified sensing equipment and that are distributed around the world. There you can find, among many others, the data in .EPW format of the AMSF for the city of Santa Fe and its surroundings (Fig. 2).

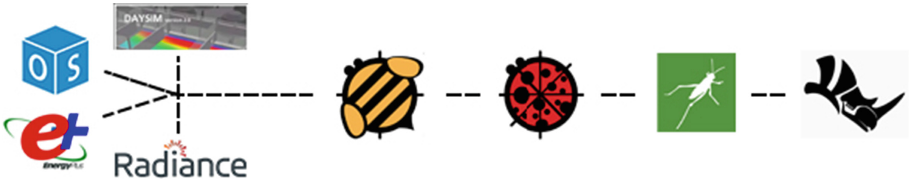

Fig. 2. Different software is used through the "Honey bee" and "Lady Bug" plugins that enter data into Grasshopper and then display it in 3D in Rhinoceros. This complex system is shown through a dynamic visualization interface that allows to appreciate the transformations in 3D models.

Once the data was obtained, the next step was to determine what type of renewable energy should be generated by the modules that make up the envelope, therefore, the previously explained data sources were used again. The analysis was limited to solar energy and wind energy as generation engines, comparing the data from the study site with other established ones. The chosen comparison site was California.

According to the California Energy Commission, 67% of the energy used comes from renewable sources, particularly wind and solar energy. Once the site was selected, the process of obtaining and verifying climate data was repeated, this time the data was obtained from the University of California Los Angeles.

First, the strength and speed of the wind were compared between the two locations. The results indicate that the region of the city of Santa Fe has the intensity of winds to power a wind generator, however, the dispersion of the wind and the constant changes in direction would make it difficult to generate energy effectively throughout the year. In turn, the comparative study of solar radiation was carried out through establishing the year 2019 as the period of analysis and the results determined that the Santa Fe region has the same potentialities for capturing solar energy taking into account the average power and constancy of solar radiation (Fig. 3).

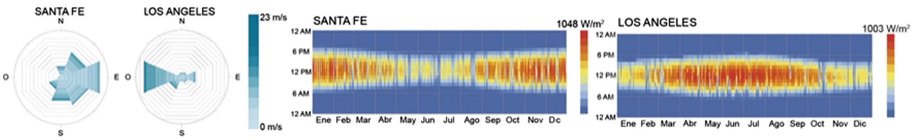

Fig. 3. Wind and Solar graphics analysis. Comparison of Santa Fe and California data.

The complexity of this study is solved through the application of parametric design. We could easily replace the cities to repeat the experience in any city in the world and analyzing the period that we want. Below you can see how the programming interface is where the components are combined to obtain results from a solar analysis (Fig. 4). In the center of the figure, in the "representation graph" sector, we could quickly change the way in which we will visualize the result.

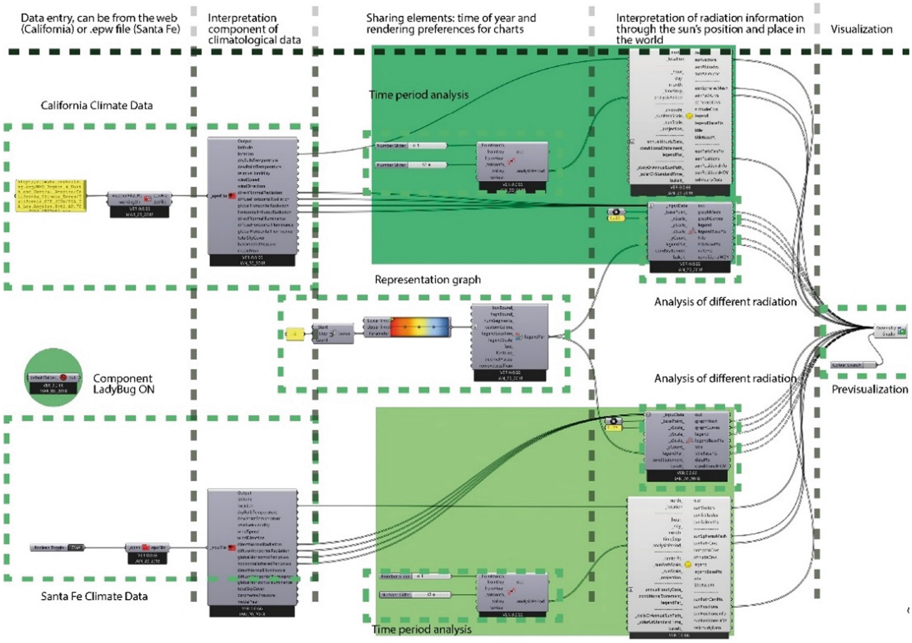

Fig. 4. Programming interface for solar data comparison. Formal Analysis.

The operation of the parametric process begins with the analysis stage. In this stage, existing space or to be built in a certain sector is evaluated, in our case we used a complex shape located in a portion of the city of Santa Fe that allowed us to appreciate the behavior of solar radiation on the piece.

You can see the different positions of the sun at different times of the year that radiate over the analyzed piece. Once the mapping over the space was completed, we proceeded to determine which areas would be usable for the capture of the sun through photovoltaic panels. Therefore, a study based on the calculation of the Peak Solar Hour (PSH) was carried out, which is then multiplied by the average reached monthly to obtain an annual solar average value that allows us to know how much energy we are producing.

The next step is to "pane" the surface according to the size of the object to achieve a proportionate result between the number of modules that the envelope occupies and the physical space that the object studied so far has. Continuing with the parametric design logic, we proceed to obtain the area and centroid of each of those sections. These points will serve to locate the designed modules, thus combining two parametric processes developed independently of each other but which will result complementary (Fig. 5).

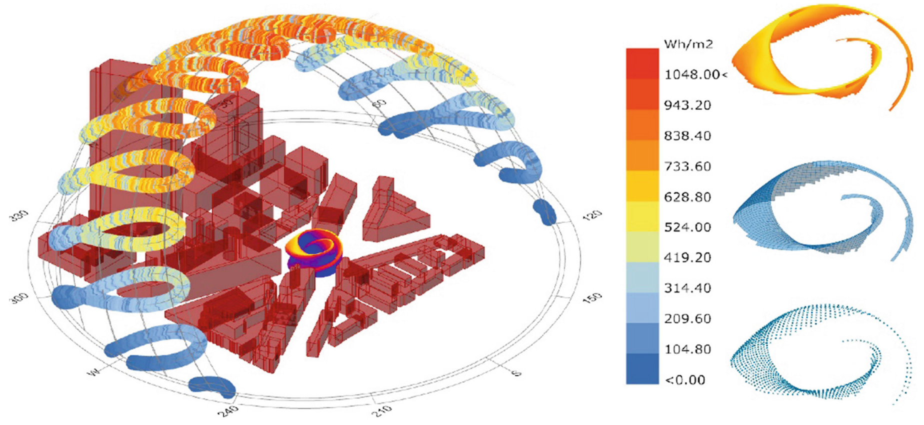

Fig. 5. Solar movement analysis in an urban context. The same system detects the areas of greatest energy benefit (PSH) and automatically cuts and detects the centers of the panels that will make up the envelopes.

So far, we could say, the analysis of the space that is intended to cover with the parameterized skin was carried out, so far, we managed to make a detailed analysis of the radiation, section according to the efficiency calculation and determine the centers to locate the modules.

3.2 Modular Skins

The skins are made up of a repeatable and recessed module that includes photovoltaic panels and different sensors that determine the movements to be made. These modules are designed by parametric design, using as conditions the maximum measures supported by the available tools (in this case, a CNC laser cutter available at the Universidad Nacional del Litoral and different 3D printers). Open-source Arduino boards are used for the programming of the modules. These boards allow the sensing and action of many components at the same time and their codes are easily modified according to the geographical location.

We studied antecedents of architectural spaces in different scales that allow us to set design premises for the modules that will make up the skins. The works studied were the Aegys Hyposurface (dECOi Studio, London, 2011), One Ocean Pavilion (SOMA Studio, Seoul, 2012), *Al Bahar Towers* (Aedas Architects, Abu Dhabi, 2014), and the *Showcase Stadium* developed for the FIFA World Cup Qatar 2022 in the city of Doha, Qatar.

When we working with parametric design, the final result is manageable at all times and allows to explore materials and supports [3]. It also allows creating "families of solutions" regarding a specific problem, so that the design is automatically modified according to the factors that will determine the formal result, such as scale, geographical location, orientation, availability of materials and, especially, the urban context where the studied building is located.

The opening and closing of the modules are made by folds that result from the mechanical movements of the structural parts. The digital simulation allows us to appreciate that, according to the position, the opening angles change, generating a high level of complexity. However, the parametric construction simplifies this process, allowing easier programming for the software of the modules (Fig. 6).

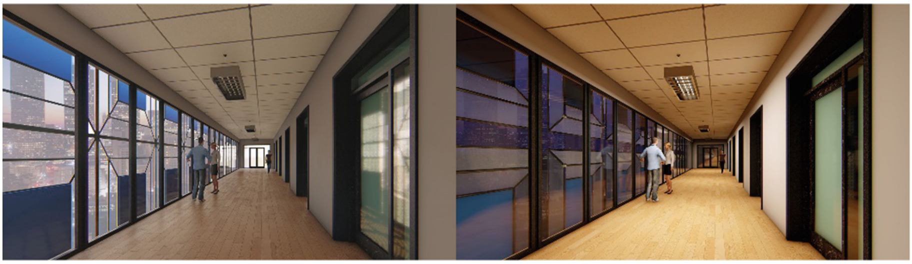

Fig. 6. The behaviour of modules located outside of a building. During the day the module unfolds filtering the sun that enters the interior. At night, the module is closed prioritizing the visuals. This movement acts differently depending on the season of the year, for example in winter the module can be programmed to remain closed and allow the sun's rays to enter.

As a result, we first obtain a set of morphological solutions that adapt to the proposed space according to the surface to be treated, altering its constitution according to the corresponding factors and, secondly, a logical programming facility related to the magnitude of the process. In this way, both parts work together and are interdependent within the parametric system developed.

4 Conclusion

We can presume that dynamic skins will not only save energy but also generate it, being able to afford their construction and installation, especially in places where the activity of prosumers is encouraged by the electricity companies. In addition, it was demonstrated that all the processes carried out so far, have been developed with parametric logic and, therefore, all the activities can be easily repeated in any location, since the climatic databases have been tested and proved convincing in comparison with the other sources consulted.

In this way, many hours of tedious and repetitive analysis work can be saved and, at the same time, a family of solutions applicable to any designed space is generated. We think that the envelopes of a building should not be just protection and enclosure, they should also be able to generate, communicate and modify themselves.

Dr Camporeale considers that the optimization based on energy performance has demonstrated its potential to integrate design and energy when applied early in the process of design, or to the rehabilitation of an existing building [4].

This research project not only generates envelopes but also conceptual processes that can continue to be developed and repeated through parametric logics to obtain formal and theoretical results at both the urban and architectural levels. the complexity of programming would have been a problem were it not for the simplicity of the visual interface.

As future work, it is intended to select a work of architecture (built or to build) and apply all the criteria developed in a digital simulation to determine if the envelopes meet the expectations of production and savings that were established in the digital experimentation phase.

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