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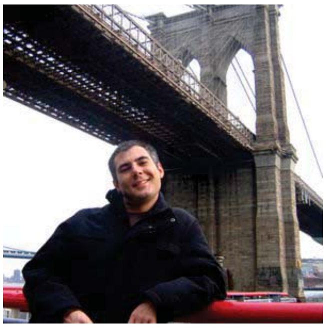
Interactive facade optimized for daylighting and pedestrian response using a genetic algorithm.



Topic: Architecture

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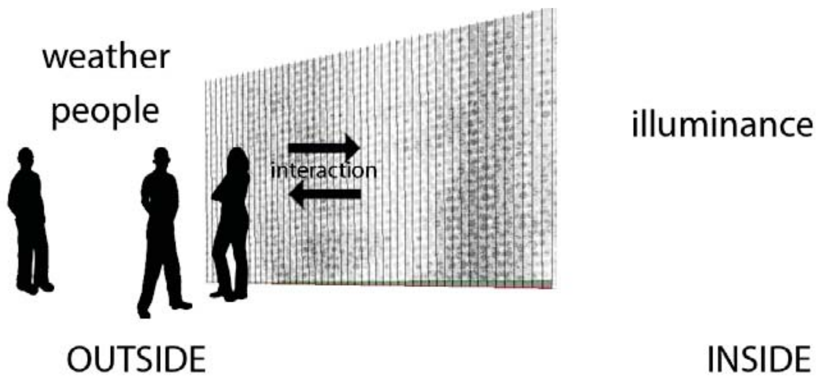
Abstract:
There are well documented studies that show the potential of the use of genetic algorithm (GA) in architecture and engineering. Numerous studies focuses on the application of the GA in the exploration of performance based façade design with single or multi-objective optimization to satisfy the illuminance and glare requirements. As part of an ongoing research on the use of the GAs in the built environment, this paper investigates on the potential of their application in an interactive façade design with a multi-objective optimization.
The objective was to develop an adaptive building façade to provide the optimum light conditions in the interior and to perform as interactive device for the exterior reacting to weather conditions and pedestrian activity. The façade act as a sort of medium to play and communicate with outside while maintain the privacy for the activities inside the building.
The façade is based on a series of shading device modules that can change aperture and tilting angles to allow to capture more or less light and to create a pattern that could change when pedestrian passed behind it to block the view through to increase the privacy in interior spaces. The façade works as interface between interior and exterior continuously reconfiguring its envelope to optimize the luminance requirements inside and the scenographic effects outside as emergent pattern and interaction with the audience.
The interaction between interior and exterior is controlled with a multi-objective GA that evaluate the different solution configuration optimizing the natural lightning inside and in the same time the pattern construction on the external side of the envelope with the interaction of the pedestrians.
The façade was designed and digitally simulated and finally was made a small scale prototype model using devices as Arduino connected with camera and sensors (Microsoft Kinect ®) to recognize gestures and interaction with users.



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Keywords:
Interactive, adaptive, facade, genetic algorithm

Interactive facade optimized for daylighting and pedestrian response using a genetic algorithm

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Premise

There are well documented studies that show the potential of the use of genetic algorithm (GA) in architecture and engineering. Numerous studies focuses on the application of the GA in the exploration of performance based façade design with single or multi-objective optimization to satisfy the illuminance and glare requirements. As part of an ongoing research on the use of the GAs in the built environment, this paper investigates on the potential of their application in an interactive façade design with a multi-objective optimization.
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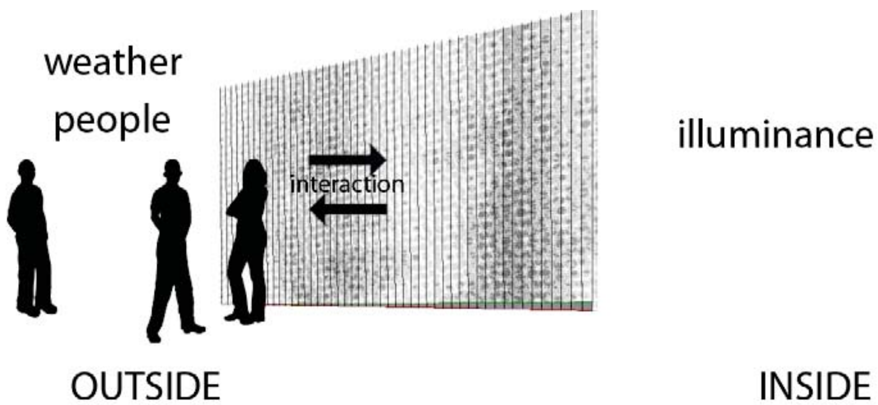
1. Introduction

The facade is often considered the most important part of a building. The designers should take into account shape, size and materials, but at the same time aesthetic and meaning as stand out features of the building. From a technical point of view the design is more focused in the control of the comfort inside the building through the correct sizing of the openings, their orientation and the use of the proper shading system to maximize the daylighting and the energy saving.
Moreover, especially in the commercial and administrative buildings, the facade has

an important role and is important the beauty, the meaning and the potential engagement with the public, as communication device for marketing purposes of the brand.
The design complexity generated by a large variety of architectural and technical objectives, can limit the research of design solutions that properly fulfill to a wide spectrum of requirements. In the analysis of such design constraints, where interact many performance variables, the genetic algorithms can be a good computation technique to explore different design solutions.
The application of this type of algorithms can explore different optimal configurations very quickly and is recognized the validity of their application in the early design stages [1-4]. Recently, the construction industry, is spreading devices that allow the automation of buildings can respond in real time to environmental data (temperature, humidity, pressure) controlling the louvers and windows configuration (aperture, tilting angles, ect).
Furthermore, the designer not only can use data from sensors inside the building, but also weather data coming directly from the Internet and coded messages through Twitter/Facebook networks according to the new vision of the Web of Things.
The market availability of several high-tech electronic devices such as smartphones, pads, sensors, actuators and the open source software and communities had generated a great interest to the design community. Designer, artists and architects can incorporate in their design small electronic devices that allows the development of interactive installations for commercial and exhibition purposes [5].
As part of an ongoing research on the use of the GAs in the built environment, this paper investigates on the potential of their application in an interactive façade design using a multi-objective optimization.

2. Method

This paper proposes a design of a prototype of an adaptive building façade to provide the optimum light conditions in the interior and to perform as interactive device for the exterior, reacting to weather conditions and pedestrian activity. The façade act as a sort of medium to play and communicate with outside while maintain the privacy for the activities inside the building.



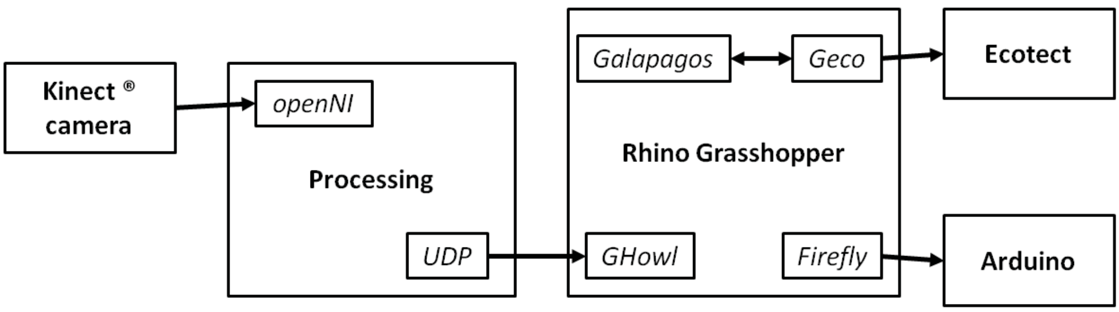
The façade works as interface between interior and exterior continuously reconfiguring its envelope to optimize the luminance requirements inside, and the scenographic effects outside as emergent pattern and interaction with the audience.
The facade may be represented as a grid, consisting of modules that are free to rotate to change the opening and allow the passage of light. As described above, the opening of several modules, and then the transparency of the facade, is influenced by environmental conditions and the presence or absence of people and their activities that they perform in front of it.
We can distinguish some main operating conditions of the facade:

a) In the absence of people:
   a.1. The facade responds only to external environmental conditions to obtain the optimal natural lighting;
   a.2. The facade displays graphic patterns and images. The modules act as pixels of a display panel;

b) In the presence of people:
   b.1. The facade responds to the passage of people and change the graphic pattern depending on the particular motion detected by the sensors;
   b.2. The facade responds to shield the view of the interior of the building ensuring the privacy of the activities that take place inside.

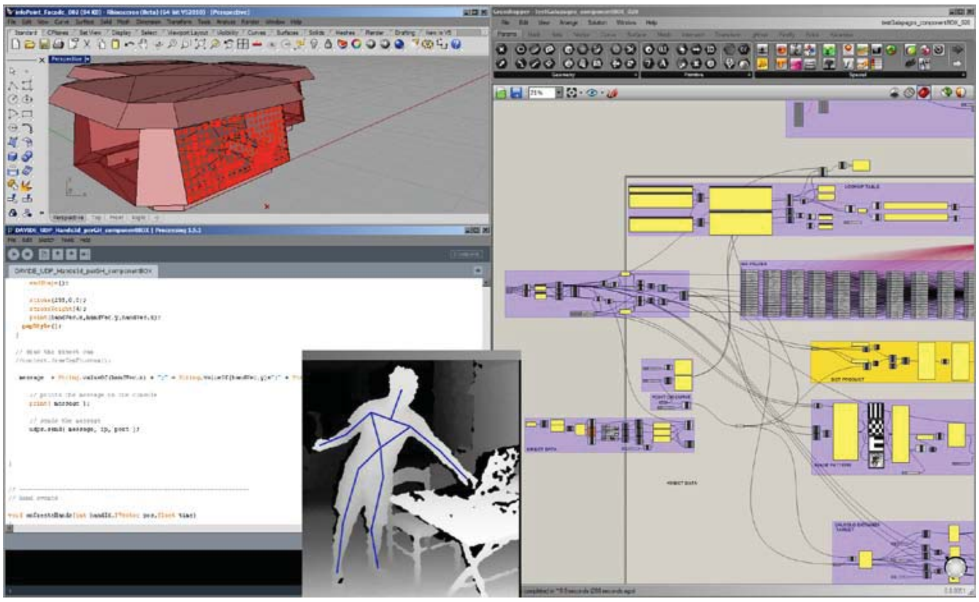
The initial conditions are defined by well-defined initial vocabulary in order to develop more complex conditions such as in relation to the number of people detected by the sensor and their behavior, as individuals or groups who walk fast, slow or stop in front of the facade. Each condition produces a particular behavior of the facade as a result of recombination and evaluation performed by the genetic algorithm. It generated over time an intelligent interactivity of the façade able to anticipate or to engage the audience in an action-reaction exchange.

The diagram show how the façade works, describing the hardware and software configuration, and the data flow through the entire process.

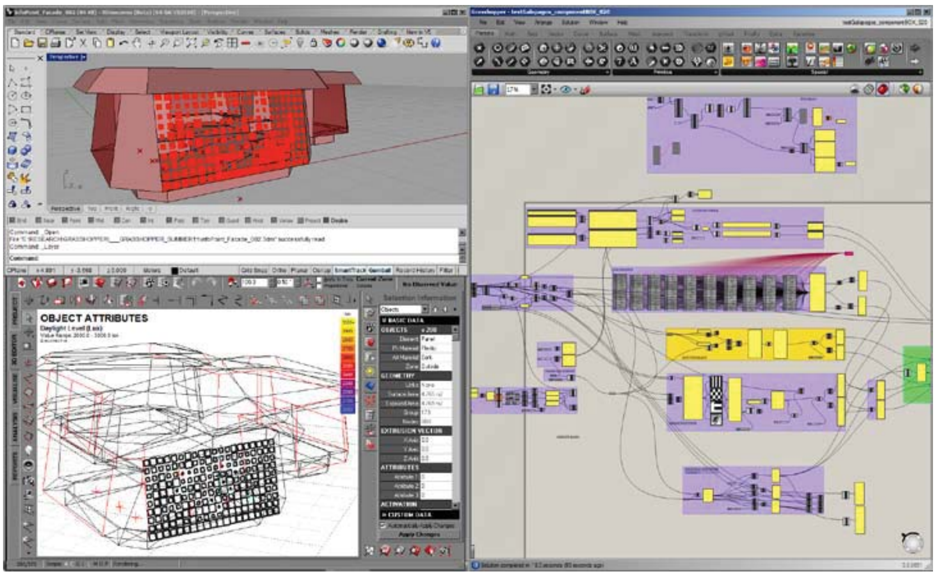


The facade collects data related to local environmental conditions through the Internet and the presence of people in the public space and spatial data with a Kinect device [6] through an infrared camera and depth sensors integrated in.
Processing [7] was used as a software platform for capturing and managing data from the Kinect. With the features of the libraries OpenNI [8] it was possible to identify people within the area of scanning and recording the coordinates x, y, z of the pelvis (identified through the function skeleton).

The platform Rhino Grasshopper [9] within different plug-ins (GHowl, Geco, Galapagos, Firefly) was used for the development and simulation of the digital model of the façade and finally, the management of the physical prototype.



The coordinates data of the people were imported from Processing through the UDP protocol, and were used to assess their position relative to the facade. The location was detected in real time and determined the different panel configurations that corresponded to the cases of the different behaviors of the facade. The configurations were the result of the optimization applied in the background provided by a genetic algorithm that computed the optimal solution to maximize the natural lighting inside the building. The genetic algorithm used a fitness function that evaluated the value of the illumination of a grid of 6 control points placed at a height of 1m from the floor. The calculation of the illumination (or solar radiation) occurred in real time by exporting the model into Ecotect and getting the sum of illuminance value in the control points.



The real-time interactive model needed very fast computational time to got solutions, and forced to set a lookup table with a set of optimal solutions calculated before. The set was updated constantly in the background taking into account the new conditions and any changes related to different environmental conditions.
The physical prototype was controlled by the digital model and used an Arduino board that controls a series of servo motors where were connected the façade panels.

3. Application

It was designed a prototype to simulate the interactive façade at the tourist info point of the city of Cagliari (Sardinia, Italy). The office is located in the city's main square, a meeting place where take place large flows of people from the adjacent railway station, bus and coach station. The office is a small structure and provides tourist information, and has large openings on all orientations of the building. The spaces adjacent to the building are large, which can allow different activities and can be adapted to the interactive testing of the facade. In the digital simulation and the prototype were tested a configuration in the south-east façade with 200 square panels of 20,5cm side, organized in a 20x10 grid.

4. Conclusion and future work

This paper has demonstrated that a facade could be in the same time an entertainment and advertising device while was a efficient and energy saving envelope that respond to environmental issues.
The work accomplished so far in the interactive simulation of the facade has demonstrated a possible application of genetic algorithms in interactive contexts, with some tricks to ensure a flow of data in real time. In this regard, it is believed that the research will be further developed towards the integration of a system of intelligent interaction that uses artificial neural networks to generate façade behavior and emerging patterns of interaction.

5. Acknowledgements

This work is part of an ongoing research supported with a scholarship by the Regione Autonoma della Sardegna (Italy) - PO Sardegna FSE 2007-2013 L.R. 7/2007 "*Promoting scientific research and innovation technology in Sardinia*".

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