High | Bombastic adaptive skin conceptual prototype for mediterranean climate

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Adaptive skin conceptual prototype for Mediterranean climate.

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ABSTRACT

High | *Bombastic* is part of a research on Living Building Envelopes still in progress at Mailab, a research center active for seven years at the University of Florence on Multimedia, Architecture, and Interaction.

High | *Bombastic* identifies the development of a naturally ventilated double-skin adaptive envelope.

This paper will present the results of the first phase dedicated to the definition and the realization of its conceptual prototype involving dynamic components and materiality speculation.

Keywords: Double Skin Facade, Active Facade, Passive Facade, Double Envelope, Double Skin Curtain Wall, Supply Air Window, Ventilated Facade, Multiple-Skin Facade, Robotic facade.

1. ORDER THROUGH FLUCTUATIONS.

> *If we now consider instead of an isolated system, a system in contact with an energy reservoir … we necessarily are confronted with open systems in which the exchanges with the external world play a capital role…*
> *In all these phenomena, an ordering mechanism not reducible to the equilibrium principle appears. For reasons to be explained later, we shall refer to this principle as order through fluctuations. One has structures which are created by the continuous flow of energy and matter from the outside world. Their maintenance requires a critical distance from equilibrium, i.e. a minimum level of dissipation. For all these reasons we have called them 'dissipative structures'.*
> – Ilya Romanovich Prigogine, 1974.

High | *Bombastic* is a research on additional external building envelope as a regulatory device/resource for adaptive architecture: a solution able to fit different climate conditions beyond the heating dominated ones representing the best contextualization and the place of its first applications. [Jaeggi, 1998; Linn, 2014] The idea is to provide ability to shape the envelope and actively participate energy flows between environment and users.

High | *Bombastic* looks to realize an efficient/active filter in opposition to the *Insulating Modernism* practice where sealing buildings, realizing the envelope as an insulated continuous barrier, and considering the building as a thermodynamic closed system persist to be used as the indisputable and universal solutions, due in particular to its robustness and simplicity. [Moe, 2014]

Conversely, *High* | *Bombastic* reject the simplistic idea that more insulation means greater well-being and economy. [Sullivan, 2011] It looks to get the best dynamic mediation between energy consumption and users' satisfaction using a reasonable amount of material and making the most of its features.

It looks to resiliency obtained by warping geometry and instancing physical properties according to climate zone, sun path, seasons' characteristics, hours and environmental conditions of the day.

High | *Bombastic* looks for an object which can mutate, adapting itself in a dynamic way; which acts as a dissipative energy architecture incorporating some kind of intelligence (under certain circumstances) able to select and to start actions in order to ensure reasonable metabolism of the living system. [Wiggington, 2002]

2. RESPONSIVE BIO-ADAPTATION. GEOMETRY AND WARPING

The energy efficiency discourse of consuming less and minimizing dissipation ultimately discloses little about the role of people, buildings, and design in the thermodynamic evolution of urbanization but does finally amplify many neoliberal dynamics. To address the non-isolated, non-equilibrium, and non-linear thermodynamics that float the operations of buildings and of life itself, architects by now need a radically different epistemology — a different ethic of work in these systems — for energy and the energy designs that will engender maximal entropy production futures for civilization.

– Iñaki Abalos, 2014

The idea for a building skin able to assume variable characteristics dated back to 1981as a radical new proposal for multifunctional glass building layers [Davies, 1981], and fifteen year later, envelopes where recognized for their *permeability*: properties enabling adjustment functions and responsive adaptations in order to have a better approximation to the optimal energy balance and users' satisfaction. [Herzog, 1996]

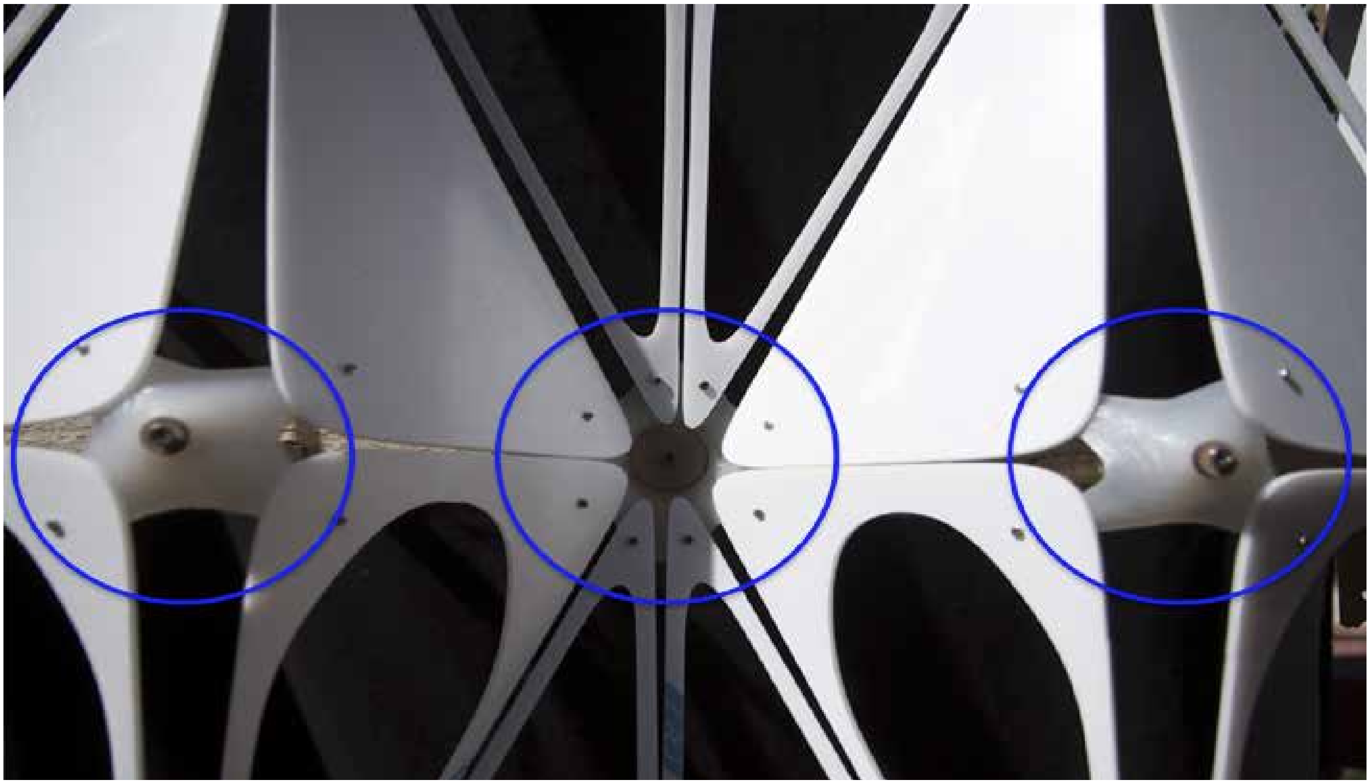
High | *Bombastic* adapts itself pursuing Bio-Logic (Bioclimatic & Passive Design), incentivizing/blocking irradiation and air; using mutant materiality able to be in-formed at different physical properties and geometry.

Based on a regular grid, the external layer is designed to assume accurate configurations through mechanical gears to get the maximum/minimum sun radiation and to resize the air cavity as it is an important regulatory device for natural ventilation. [Faist, 1998, Oesterle, 2000, Stec 2000, Compagno, 2002]

To allow movements, external elements are designed as on origami diagram made of rigid triangles able to warp the surface but maintaining the perimeter of the façade bound profile unchanged. [Tachi, 2011]

For the property of origami, the perimeter constrains required deformations in the façade surface that has been realized providing punctual elastic joints between its triangular components.

previous page: inflating/deflating cushion test
this page: punctual elastic joints



3. JOINING AND MODELING

The architect no longer designs the final form but rather creates an initial state, introduces a set of controlled constraints, and then allows the structure to be activated to find its form. – Farahi Bouzanjani Behnaz, 2016

The use of punctual joints is a temporary solution useful for conducting preliminary test on the prototype but not satisfactory from the standpoint of the façade sealing as the spaces between the elements, produced in the various configurations, at this point of the research are not negligible.

The research is currently investigating how these gaps can be used as a regulatory device on *permeability.* [Poirazis, 2004] On the other hand, materials & technologies with passive/active deformability and continuity on surface to ensure an airtight buffer are under studying. [Kwinter (1993); Beesley, Khan (2013); Fortmeyer, Linn (2014); Bouzanjani (2016)]

According typological classifications [Kragh, 2000; Poirazis, 2004; Parkin, 2004; Loncour 2004], we are dealing with different «functional models» which go from *naturally ventilated buffer* up to the *air tight made box* trying to fit them on Mediterranean Climate Zone.

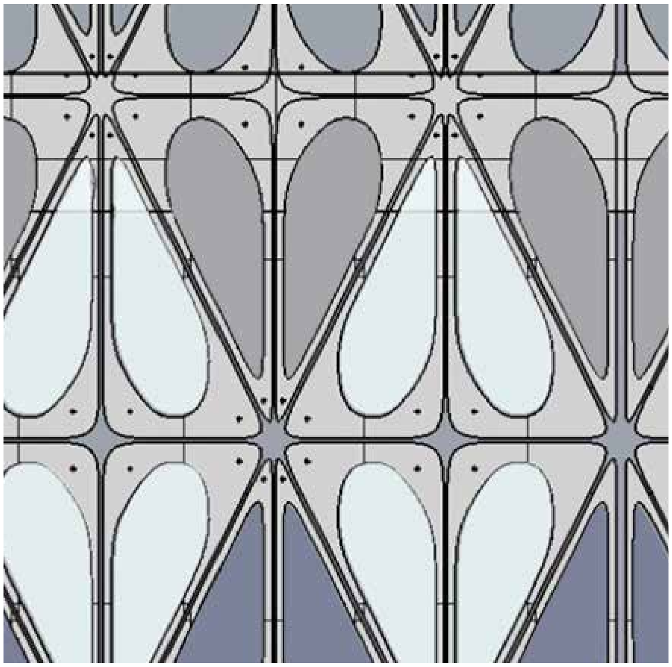
Parent Components. The triangular panels host three different parent components able to mutate thermal property; to activate/deactivate stack effects inside the air cavity; to regulate energy flows. These components are:

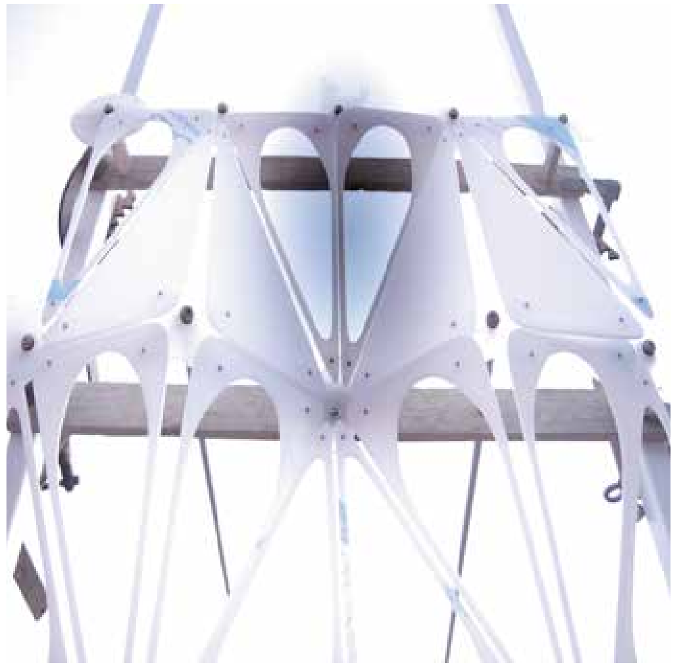
- pneumatic driven cushions
- memory alloy driven flaps
- windows.

For the dynamic cushions two main alternatives are under investigation.

The first one is a three-layer teflon-coated pillow where it can change its characteristics inflating/deflating the inner and outer air cavities. Taking advantage of this movement and the special treatment of the films, where opaque and transparent parts are alternated, it is possible to obtain a different alignment of the parts permeable to the light and consequently a precise regulation of the incoming natural light and connected internal irradiation.

The second one is based on standard ETFE pillows where the Argon will replace the natural air used to inflate them in order to decrease its thermal conductivity of about 67%. In fact, and as well known, thermal conductivity of Argon is 0,0168 W/mK where air is 0,025 W/mK. The different inflation of the cushion is then used to adjust the thermal energy of the system.





Another component of the façade is an opaque semi rigid flap that can be open up when the air cavity is overheated to increase permeability and its hot air dissipation capacity. [Oesterle et al., 2001]

To operate the flap, *High* | *Bombastic* uses the property of nitinol (500 nm 55-75 °C wire), a metal alloy that change its state and length when the temperature reaches a predetermined temperature.

Nitinol is the commercial name of the metal alloy of nickel and titanium able to assume, under higher temperature a crystal cubic structure as well known as austenite and, when cooled, to reverse at its original configuration of martensite. [Axel, 2007] This structural transformation induced, on the wire a difference in length of around 6-7% that can be used to pull and release the flap.

In short, when the wire is heated and the nitinol changes to its austenite state, a contraction occurs, conversely when the wire get back to a normal temperature the wire recovers its original length. A very interesting property of nitinol is also the fact that the changing state temperature can be predetermined by «cooking» it at a specific temperature in a way it is possible to operate the opening of the flaps when the air in the cavity reaches pre assigned temperatures of excessive overheating.

As a result, flaps do not require the use of any detector and any actuator device requiring energy.

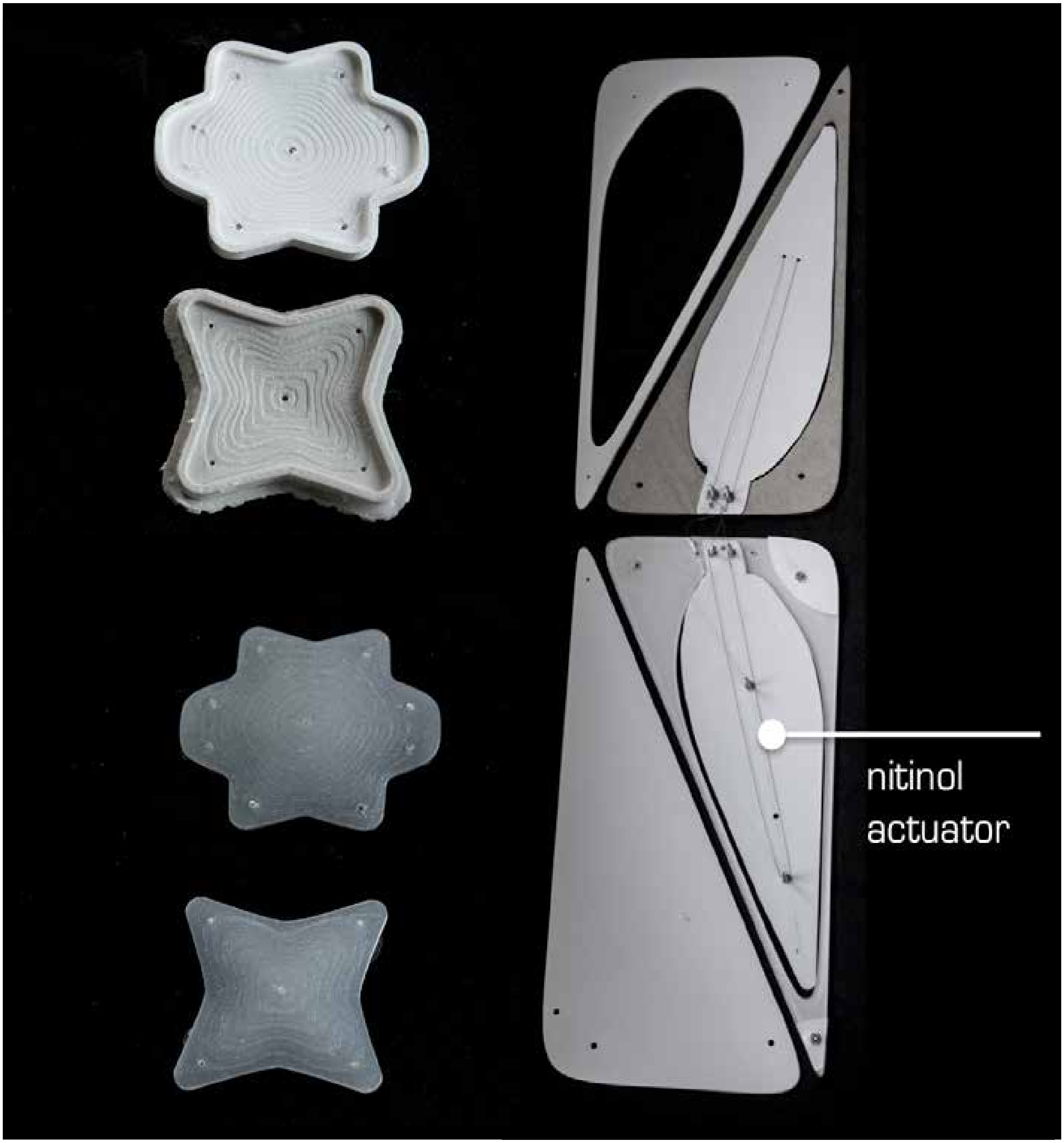
The last component is a traditional glazed surface that can be defined in its technical characteristic according to the required performance of the façade.

Windows positions represent the qualifying element of glazing where the sill is at the same level of the floor and the window height not exceeds two meters high. In fact, considering that the double skin façade is normally used in large buildings such as offices, commercials, hospitals,... the research has set two fundamental goals: the first one to provide a better visibility towards the outside for users sitting at working table or lying in bed; the second one to provide a sensible glaring reduction in the room.

To meet these goals, and at the same time to ensure optimal energy behavior, the façade can take benefits from its geometric changes and the selective properties of the cushions on the sun's rays.

previous page: diagrams and components
initial frame prototype

this page: molding silicone joints
initial flaps prototypes



4. CONFIGURATIONS FOR MEDITERRANEAN CLIMATE.

The prototype assumed as reference the Mediterranean climate (3C | Mediterranean North) and is currently under evaluation for different configurations in relation to six different environmental conditions.

- sunny winter days
- cloudy winter days
- winter nights
- normal summer days
- hottest hours of the days
- summer nights.

In the first condition, the façade frame assumes a concave configuration in order to increase the capturing surface of the glazed components and to achieve an angle of incidence with the solar irradiation closest to the ninety degrees. In this configuration cushions remain deflated in order to promote the thermal gain derived from the sun presence. Flaps are closed.

In the second condition, occurring during a cloudy winter day, the facade is fitted to completely seal the air-cavity and limiting stack effects that normally take place inside this space. In this configuration cushions are inflated to increase thermal insulation and flaps are closed.

The above configuration is the same that is assumed for the winter nights where the goal is to limit the flow of energy from the indoor space to the outdoor environment with lower temperatures. During the summer period the façade predominantly assumes the convex configuration in order to obtain the maximum shading and cushions can be inflated in order to increase insulation. In case of the three-layer solution, the cushions can be adjusted in such a way as to obtain the best compromise between thermal insulation and room illumination.

During the hottest hours and when the temperature inside the air cavity reaches high temperatures, flaps are activated in order to let the hot air to flow out. The last geometry occurs during the summer nights where the double skin facade is well known as an effective device to extract excess temperature from the indoor environment. In this situation the façade is planar realizing a sealed chimney with lower and upper openings for cold air intake and hot air exhalation.

5. THE PROTOTYPE & ENERGY MODELING

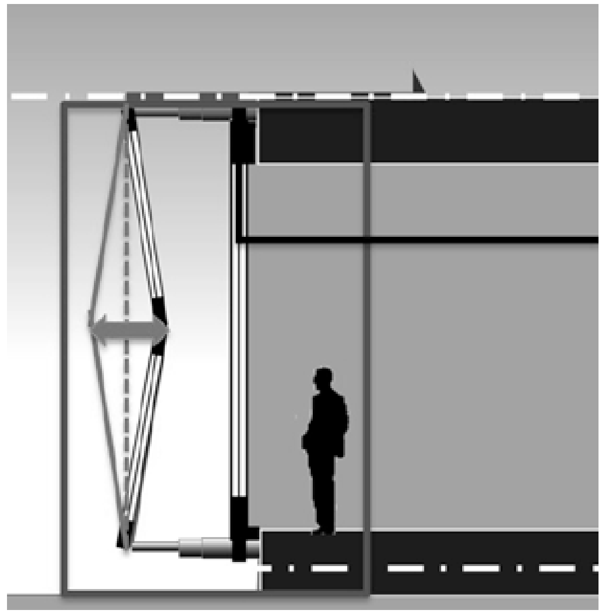
A prototype fabrication and energy modeling have been undertaken to verify the design hypotheses. Although energy simulation is primarily used in the design detail stage, a very useful benefit can come if applied in the early stage [AIA 2016] . Besides the fact that energy simulation is based on a computer program and the accuracy of results would largely depend on the inputs provided, many useful feedbacks can be gotten in the simplified mass modeling of the early stage. [Lawrence 2006, Nilesh, 2016]

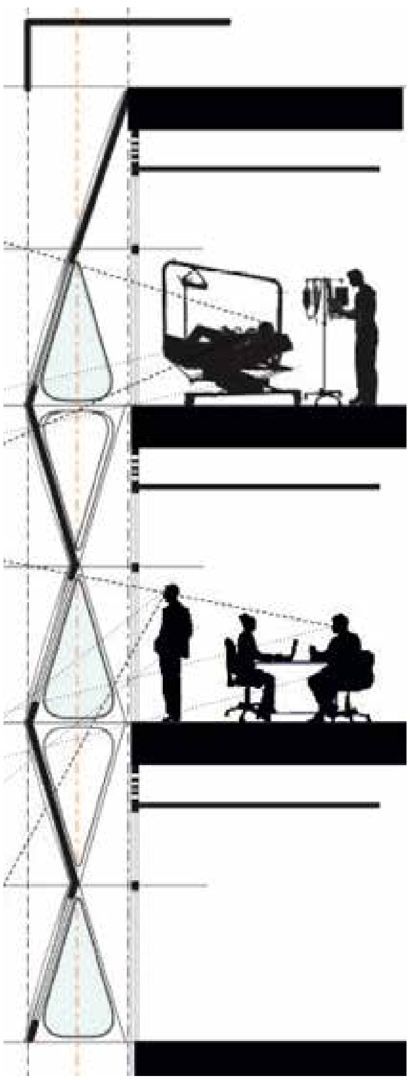
In addition, the physical prototype and the related digital modeling have also been entrusted with an educational role and used during the Mailab's international workshop «Parametric Computation and Digital Prototyping for Environmental Responsive Envelopes» hold on 2016, Florence, Sep. 5th-16th.

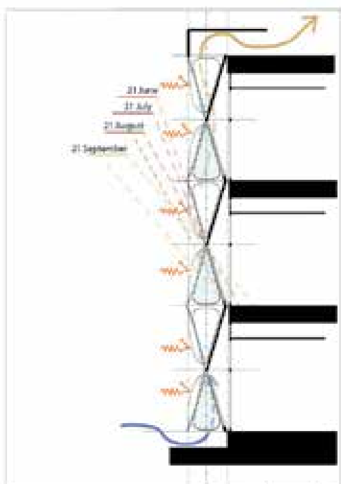
In fact, we think that besides being a research tool, modeling is also a valid educational instrument giving intuitive perception about matter's behaviors. In this case, the model is used, not as a mere presentation of phenomena, but as a cognitive artifact that allows students to interact and become familiar with the theoretical foundations that the prototype incorporates: expression of concrete thought and formalization of the traditional sketching in a way it can be now used as a shareable instrument of scientific research. [Papert, 1996]

For this goal, numerical analysis were translated in more understandable and shareable info-graphics to give evidence of immaterial aspects of design such as temperature, wind, light, ...

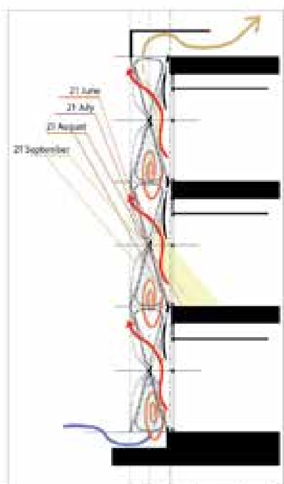
this page: concave/convex outward visibility analysis façade configurations



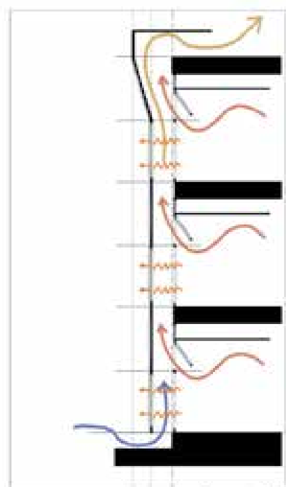




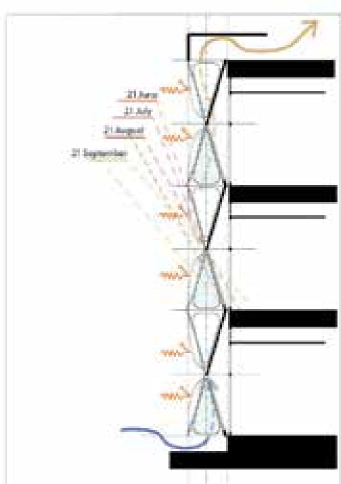
sunny winter days



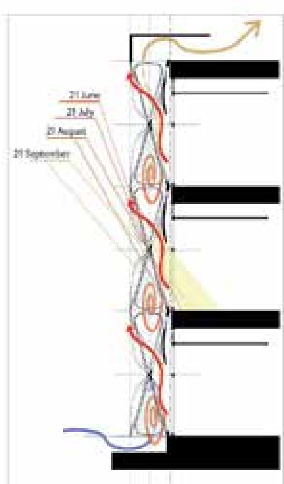
cloudy winter days



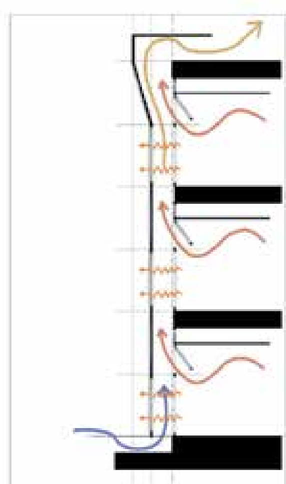
winter nights



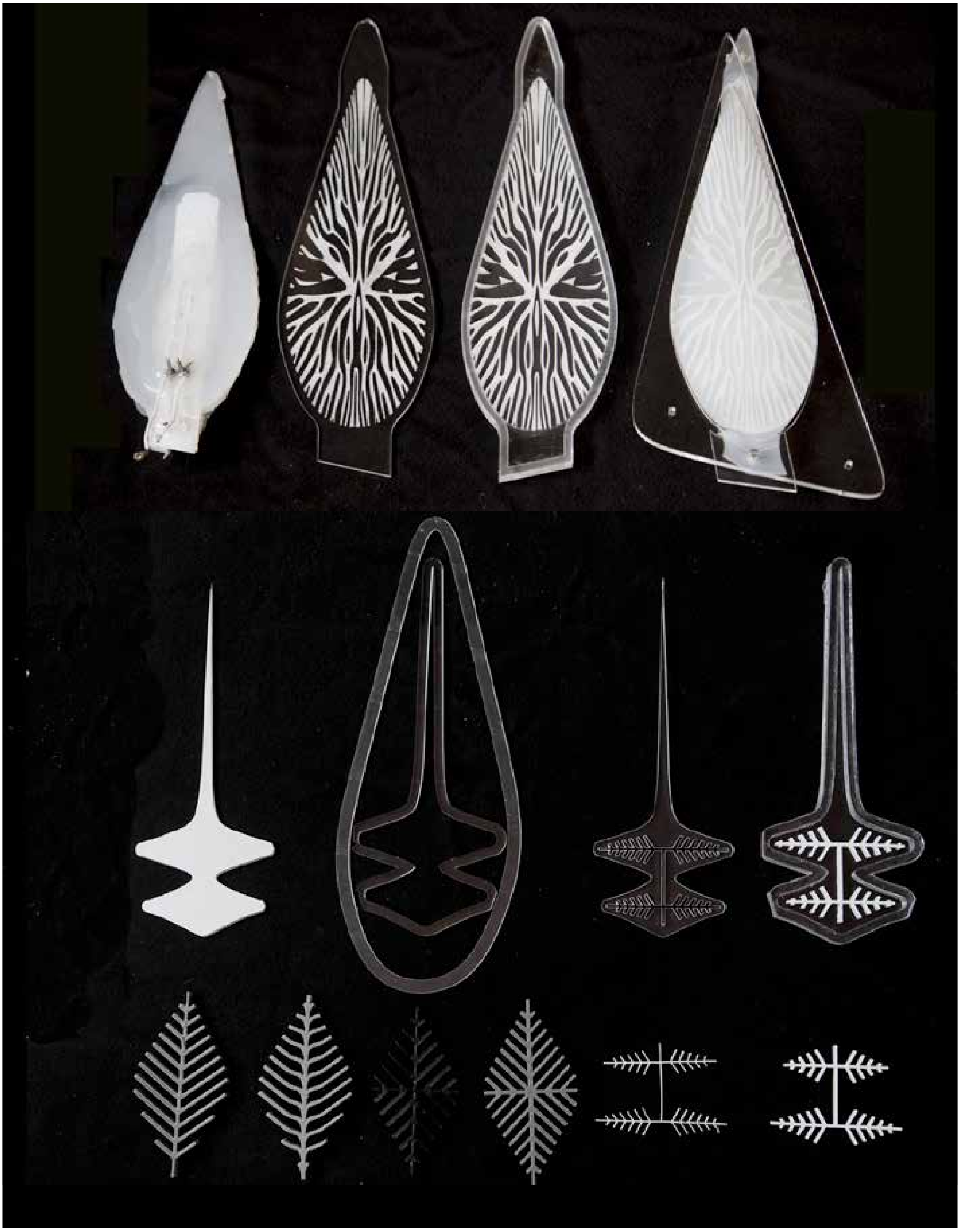
normal summer days



hottest hours of the day



summer nights



previous page: silicone components and air cushion casting elements

Therefore 3D visualizations and graphic animations were produced to show the changing state of the façade under different conditions of forms, building elements, weather and time as the complementary entity of form and matter.

The model is composed of two main parts: a sample of the façade fabricated in a 1:10 scale robotic model; a screen for video projection showing the physical effects on the building.

Numerous researches and tests have been carried out in order to identify a material capable of supporting the geometric transformations of the façade.

At this stage the solution has been identified in the construction of rigid frames connected through casted joints made of silicone with hardness characteristics between shore 00-20 and shore 00-40.

Silicone with harder characteristics (shore A-40 and shore A-80) was also tested for the flaps components but with unsatisfactory results that have decreed the use of common 3mm Plexiglass.

Because of the gaps between the elements produced by elastic joints, the extensive use of silicon membrane or other equivalent material is currently under test for the whole façade system.

The façade movements were made through the use of pistons driven by digital servo with a standing torque of 15 kg.cm at 6.0 volt.

In this preliminary phase, cushions were simulated using a thin silicone membrane but a deeper research is currently under way in order to investigate potentiality and feasibility of polyester coated films.

6. THE INTERACTIVE INSTALLATION

To reinforce the didactic power of the model an interactive installation was also realized.

A portable device is used as the users' interface to set a scenario between different environmental conditions. The choice is processed and sent to the computer via Wi-Fi using the OSC (Open Sound Control) protocol.

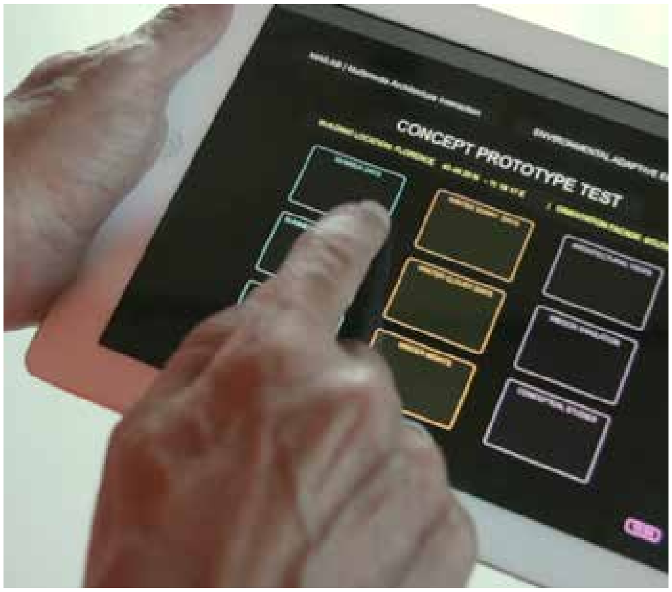
The core of the system is managed by Isadora, a graphic programming environment, that allows the real time synchronization of video/audio contents and digital signals activating the mechanical parts of the model.

Another important component is represented by Arduino the most famous open-source digital prototyping platform used to realize interactive electronic objects. All the signals coming from Isadora are processed inside Arduino in a way servo can be activated in relationship to the selected environmental scenario.

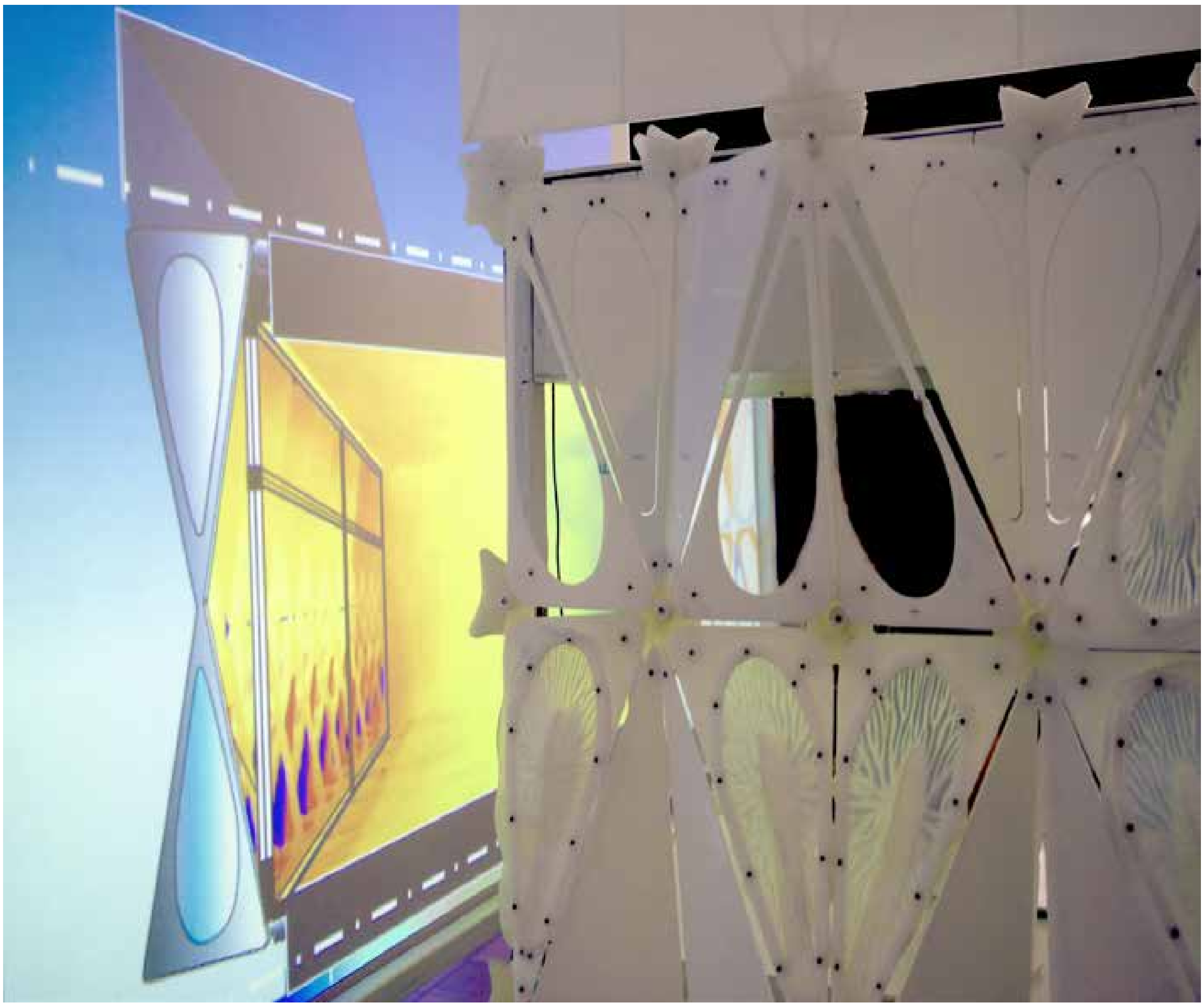
At the same time Isadora starts different video animations that are sent and projected on the side screen in order to show which kind of effects are produced inside the building.

Results coming out from analytical calculations have shown that the proposed solution, compared to simple sealed double skin facade and to a normal solution on layer envelope, produces a better thermal performance and a better distribution of the natural daylight with a very low percentage of glaring during the day and the whole year.

In detail, results show that natural daylight reaches a better distribution with glaring slightly perceptible in the worst condition (≤ 15 in Unified Glare Rating scale); Energy Use Intensity in different building program has always been better for a ratio of about 20-35%. Other benchmarking, based on Performance Metric for Green and Smart Building [Nileh 2016], are currently under study.



this page: OSC Tablet interface
High | Bombastic, interactive installation



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