Parametric Surface Approach to Textile Façade Cladding for Sustainable Buildings

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Abstract

There have been considerable efforts to develop systems to improve energy savings for the last couple of years. The focus in developing such systems are making most of external light, most of heat during winter and protection from excessive radiation during summer.

Despite high popularity of glass façade cladding, it usually ignores locality of the building, let alone changing climatic conditions in proximity of the building. As a result, air conditioning systems are expected to solve the problem at expense of excessive use of resources. In fact, controlling air temperature and humidity can not compensate for solar radiation influence to provide good comfort.

New façade cladding materials are always produced to address this issue. The easiest and the most popular way of cladding by a porous planar screen which is parallel to the façade leads to two issues: the monotony and existence of a constant vertical cavity.

In this study, a parametric surface approach has been taken to produce a façade with a patterned design so that the vertical cavity between the façade and the screen could change providing different forms of ventilation, more precisely in response to wind direction, and at the same time, give esthetical freedom of "living façade".

Two models have been developed. First one takes the benefit of multiple combinations of a single hypar. Through a specific software, it is possible to divide a façade in multiple rectangles, each being a separate hypar.

The second model consists of rectangles which generates a non planar surface for the whole façade. Only the spherical surfaces has been studied, but any parametric surface could easily be adopted.

The first model is more repetitive but can control ventilation much better. The second one gives more studied surfaces but the inner cavity will control ventilation in a poor way.

Keywords: parametric façade textile sustainability

1   The market

For many years, manufacturers of textile architecture have found a very interesting and profitable market albeit in a wrong way to protec building façades from sun radiation. It is not the goal of this paper to deep into the origin of this misdesign, but it is quite obvious that all glass façade buildings do not behave properly in hot climates, not even in temperate Mediterranean climates, or even in any climate at all.

Sun is a source of energy, which hits on buildings accordingly to their latitude and the season of the year. This energy can be perceived either as an extreme light level or as a heat radiation (or both), the latter being appreciated in cold environment but as undesirable in warm o tempered environment.

The excess of light will rarely be appreciated for any normal activity as it produces glare. So, most of the time a glass façade, hit by the sun, must be dimmed by any means, and one of the most effective solutions has been the use of textile screens as a light barrier. However, this solution represents a great disturbance in the outdoor perception of the users within building. The same happens if special dark glasses instead of screens are used.

It is even worse with high heat gains. We assume that we are talking about well conditioned buildings, with a comfortable inner temperature. If any person working in this building gets into the scope of sun radiation, he/she will notice a very unpleasant feeling of heat from the sun side. If the room is heated (winter) the excess of heat is clear, but even in summer, when the room might be air conditioned (cooled) in summer this will result in an unpleasant feeling as well, regardless how low the room temperature is. Being one side cold whilst the other side hot is not comfort, it is double discomfort!

It is sufficient only to look at web sites of most of architecture textile manufacturers' web sites to observe how they have created branches to deal with this issue [1]. Solar screens, that is, fabrics with separated threads in both warp and weft directions, or just in one direction, allow only the desired amount of energy inside. And curiously, although the clear area through the screen can be much reduced (less than 10%), the vision through it provides an adequate view of outdoors.

Some times, these protections are integral part of the shutters or blinds system, and they are deigned from the beginning as part of the whole building design. But most of the time, these elements are implemented *a posteriori*,

Figure 1. Offices
Deutschland - Soltis® 92

Figure 2. School center
Switzerland - Soltis® 92

2   Continuum

From 2007 to 2009, my school (E.T.S. Arquitectura del Vallès [2]) participated in a European Lifelong Learning Programme called Continuum [3]. This programme included two workshops where students should practice on the subject: file to factory, that is, how to prepare drawings to be translated directly to the manufacturers machines.

The first workshop took place in September 2008 at the Grands Ateliers in Lyon (France). Each participating school prepared an architectural object that should be constructed and erected during the workshop week. Our school prepared an exercise about façades sun protection. Moreover, materials to be used in this workshop must be those provided by the industries that had participated in the Programme. We decided to use:

1. cardboard cores, to simulate structural steel tubes (delivered by ABZAC)

2. PVC coated polyester fabric membrane, as a real material to be used (delivered by FERRARI).

The idea came out by observing existing flat façade protections, where the only possibility to give some design touch was to use different colours or just painting directly the screen. What we proposed was to give volume to the façade.

In this sense we created a small piece of software (in situ, during the workshop) where students investigated how different surfaces on the façade could be created, just manipulating a few set of parameters.

Most of façades have a regular square pattern. Each subsequent floor delimit a vertical level that is usually divided into three parts: window, bellow and over. And horizontally, limits are vertical structural struts separated conveniently. This model shows a set of rectangles that will be our starting point for our research.

This way the first parameters to be fixed were the size of these rectangles: W, H. We know that very often vertical size of rectangles are not the same (window, bellow and over), but just for the sake of simplicity we used a single size. Then we fix the

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number of rows and columns of rectangles on the façade. Finally t is the value of the distance between rectangles. Up to now, we have a flat protection.
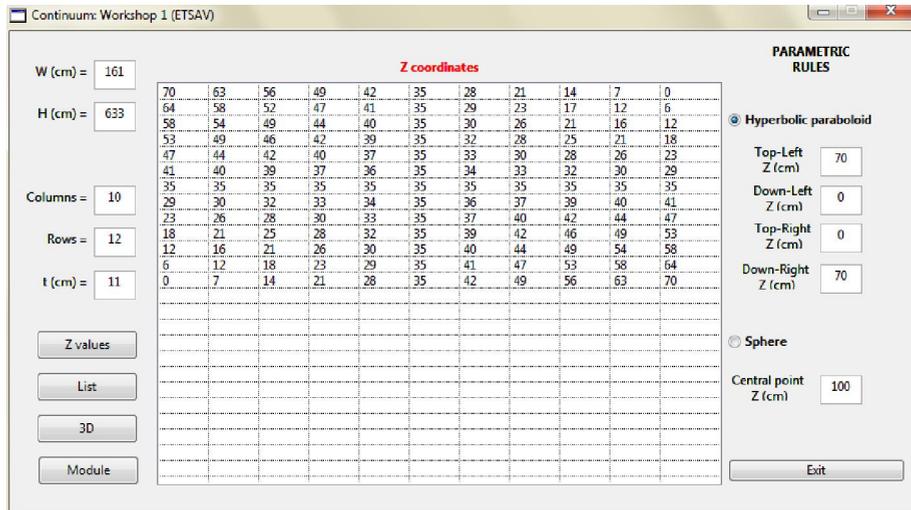
Figure 3. Continuum piece of software

So, the following step is giving volume to the façade. For the workshop example, this piece of software proposed two possibilities:

1. the whole façade surface is a hyperbolic paraboloid. To define it we must fix the horizontal outwards (Z) values of the four vertices of the façade.

2. the whole façade surface is part of a sphere, which centre vertical coordinate is at the centre of the façade. To define it we suppose that the four vertices have a value of Z=0 and we adjust only the central point of the façade with a single Z value

Changing parameters values and pressing *Z-values* button we update the table shown in Figure 3. With the other buttons we had some more information of the proposal.
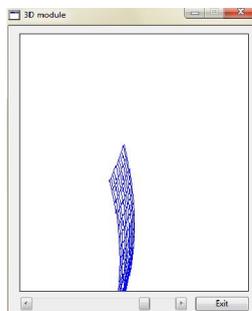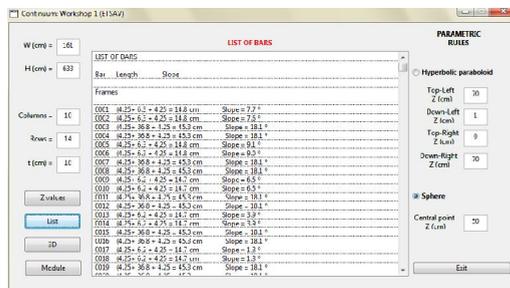
Figure 4. A very simple 3D view of the façade

Figure 5. List of bars, with their lengths and folding angles

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3D button shows a very simple image of the resulting surface. You can rotate it horizontally just to observe if you got what you pretended (Figure 4).

List button gives us a list of all the perimetrical bars for each rectangle. These bars must be folded at the ends so that they can be connected together. This folding angle is also given in the list (Figure 5).

Finally *Module* button gave us complete information of every single rectangle in the façade.

Figure 6. An example of the object built during the workshop

3   Parametric architecture

The second workshop took place in May 2009 in our school. In this case, new objects were built and intention was more focused on parametric geometry. Although we worked on different objects and façade protection was left aside, it is clear that the recipes we managed in this second workshop can be applied to the object we worked on during the first workshop.

The idea is to use all the means we currently have for parametric geometry in order to provide a wider set of solutions in façade shading. But we want to preserve what made it very simple: a grid of rectangles based on floor and struts distances.

Taking advantage of one of the courses I give about parametric architecture, we have worked with Grasshopper & Rhinoceros software. With this tool, it's very easy to provide a façade with a wide range of possible surfaces, just manipulating a few nodes. These nodes will generate a NURBS surface which will be decomposed into a grid of rectangles. Obviously, these rectangles won't be flat, since four corners will not be on the same plane, as a regular basis. We can call them "quads", which is a more general term for a non planar four sided polygon.

Figure 7. Building without screen protection.

Figure 8. Final image of a protected building (Render made by the student Marc Farres)

Creating a complex surface will be the first step in this new approach to our final object. Not only Rhinocerus-Grasshopper will serve to this purpose but any other software as Generative Components or similar. And, obviously, there is the possibility to create a dedicate software exclusively for this job.
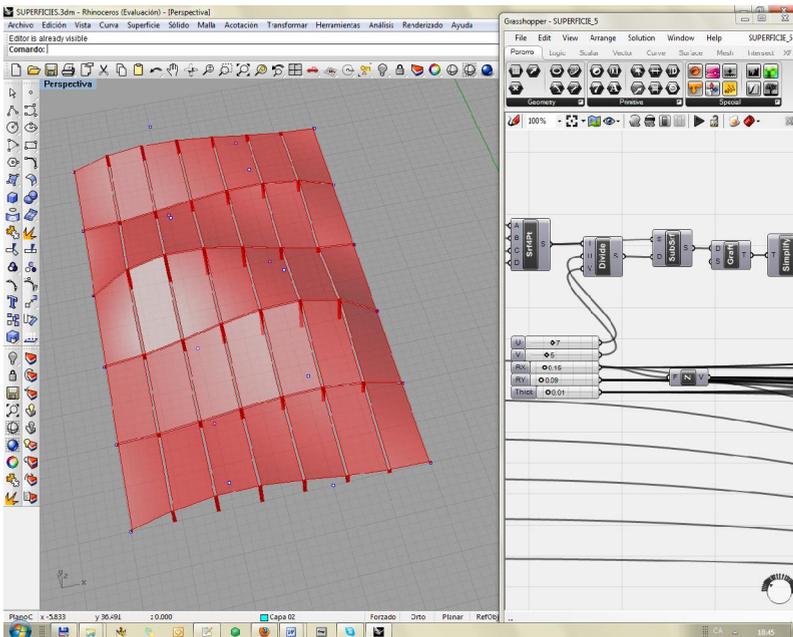
Figure 9. Model of undulated façade created from a script in Grasshopper

Basically, work will continue from this idea and will give the next step. A simple but important step: *Node disaggregation*.

Each quad has four vertices. And vertices are assembled in groups of four (except at the boundary). Up to now this four vertices assembled at every grid node are practically together, since the surface is continuous and only the gap between quads can give a small difference of depth of this vertices.

Disaggregating these vertices means that each vertex can have a particular depth, independently of the others. This simple action will produce a lot of difference, and will give to this text its real value. To start, we can imagine that at every grid node one of the vertices (let's suppose the top-right of every quad is pull outwards). This action creates two triangles of discontinuity between continuous quads, one vertical and one horizontal. And these open triangles can influence many comfort parameters of the façade.

4 Ventilation

Screen protected façades are considered ventilated façades. This type of façades containing a cavity between the outer layer (the screen) and the inner layer (the façade) are thought to have a better thermal behaviour in front of heat produce by sun radiation. And this is true as long as the cavity dimensions are sufficient.

According to the whole surface of the façade and to the thickness of the cavity we can calculate which will be the minimum in-and-out opening area in order to ensure efficient ventilation. When façades are very big, both wide or high, but mainly in high buildings, in opening is just the space between the screen an the building at the bottom of the screen. And most of the times, this area is not enough. At the top of the façade it can be worse, especially when some rain protections interfere with the draught of the air through the cavity. Side openings (if really open, since sometimes they are closed for aesthetics reasons) will only contribute to ventilation in case on tangent wind.

If the triangles mentioned in the previous section are considered, we can improve in a very significant way this opening area.

As every dimension, including the "*node disaggregation*" is done thought parametric design, we can know at any moment, just changing the depth of the disaggregation, which is the real opening area for in and out air movement. And not only for convection movements (which are produced naturally by the sun radiation) but also for the wind that blows against or just tangentially to the building.

5 Light & Views

We use to say to our students: be careful with west façades! In Mediterranean countries, and in many other situations, west façades receive sun radiation perpendicu-

larly (maximum) when the air temperature is higher. Eaves or brise-soleils are not effective since sun radiation impacts buildings quite horizontally.

There are not easy solutions for this problem and the best ones are related with vertical slats. Again a normal continuous solar screen will be a poor solution to the problem. Its continuity will prevent user to have any free view outdoors, and at the same time the natural light level will be poor as well.

Light and views are more difficult to harness than ventilation. Orientation of the façade must take into account; opening areas of triangles formed when disaggregating nodes and their own orientation as well, so combining both orientations (façade and triangles) light entrance and external views will be known. Fortunately, parametric software will do (after some programming) the hard work.

6 Construction

This is the last but not least. And never better applied! All what has been explained in this text could be very exciting, but if its application supposes lots of details, lots of drawings and hard work to prepare components, then all this is just noise!

So, we have to propose, in parallel with design a process to construct it. We know that parametric architecture goes together with CNC construction. Producing elements must be the normal conclusion of the design of the façade protection, and it must be an easy, not expensive, fast and beautiful conclusion. And this is not straightaway.

Probably a good solution for this implementation could be object of a patent. So it is obvious that we are not going to propose anything here, but this study will conclude showing which the points this solution should deal with are:

1. Screen protection structure will connect the façade structure just through the nodes of the grid formed by vertical struts and horizontal rails.

2. From this point, pegs (elements perpendicular to the façade, thus normally horizontal) will point outwards with different length at every node. Only the length of the peg will change, not the end details.

3. The peg will provide a system to create four anchorages (the corners of the four quads that touch this node), each one at different depth.

4. Quads are not flat pieces of membrane. Basically they are small hyperbolic paraboloids, so we should use patterning to simulate them, which will mean lot of work and being expensive. There are two solutions:

a. Quads are divided into two triangles; any of the two diagonals can be used.

b. Quads are cut as a rectangle with curved sides so that they will conform sort of hypar when stressed in place.

5. Borders of quads can be:

a. Bold ropes, which are cables in hems at quad perimeter. This cables will finished with terminal which will fit easily at pegs' anchorages. Spaces or gaps in-between quads will be spindle shaped.

b. Tubes also in hems, so that they will allow rigid borders. This way spaces or gaps between quads can be as small as necessary.

6. Finally, the fixing process design must be proposed, so that this job can be done in a fast and reliable way.

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[4]