INTRODUCTION
In 1956 the Philips art director, Lois Kalff, asked Le Corbusier to design a Pavilion for the 1958 Expo exhibition in Brussels. As the assistant of the architect, the engineer Iannis Xenakis, remembered, Kalff required to Le Corbusier some detailed information: “I would like that you design the Philips Pavilion without exhibiting our products. A demonstration among the most ambitious about the effects of sound and light, where the technical progress could lead in the future” (Xenakis 1976). The architecture, called by Le Corbusier ‘Poème Électronique’, using an oxymoron of undoubted efficacy, which refers at the same time to the natural idea of the poetry and the artificial component of the technology, should be among the most influential and pioneering works of the twentieth century, for the specific role in the field of the presentation of the idea of future, as a game of colors, lights, sounds, videos.

The aim of this research was to study the geometrical genesis of the project, in order to understand all the particular surfaces that characterize the volume of the building, trying to describe the procedure used by the designers to generate them physically and to re-build every form with digital instruments to compare the different models in the way it is possible to do.

To remember some important dates of the project, we have to consider that Le Corbusier accepted the proposal on 13 October 1956, and some days after there was the first idea of the form. In November there were some detailed drawings on the sketchbook of the architect and in December the second solution of the project was defined at the 1:200 graphical scale. In the meanwhile some physical models were realized in order to comprehend the complex morphology of the architecture, and to verify the analysis of the deformation of the structure.

Abstract. The aim of this academic research was to analyze one of the first architectures designed and built with the finality to present electronic potentialities to people. The design was developed by Le Corbusier and his studio for the International Expo held in Brussels in 1958, for the Philips firm, and it was destroyed some months later, after the event. The research investigated the complex geometry of the structure in order to understand the strict relation between the physical perception of the space and the electronic aspects of them, using advanced technology, but, above all, if it is true that the best way to understand the physicality of a destroyed architecture could be a virtual visit using electronic devices and digital procedures.

Keywords. Architecture; digital reconstruction; virtual space; geometry; representation.
After the studies of the geometrical form, there were the ideas of the organization of the event in which the participants should be involved during the performance. Le Corbusier decided to ask to Edgar Varèse to find the soundtrack of a video that should be projected on the interior walls of the pavilion. Despite the opposition of Philips, that did not like the music of the composer, in September 1957 Varèse arrived in Netherland to define the final music composition. On 17 April 1958 there was the official inauguration of the Pavilion, but immediately it was closed to be re-opened on 2 May, due to the complexity of the system. After six months of free exhibition during the Expo and about two millions of visitors, on 30 January 1959 the architecture was destroyed, otherwise there was a proposal of Le Corbusier to transform it in a center of scientific research.

As Xenakis said: “In October 1956, Le Corbusier proposed to ‘translate mathematically’ some ideas. He gave me a sketch. Le Corbusier [asked me] to look for a form of a bottle containing the ‘nectar of the visual presentation and of the music’ for the building. For the cinematographic show, he wanted to have vertical walls. For the spatial effect, he asked a bottleneck tapered up to the roof of the pavilion where the projected images would disappear” (Xenakis 1976). Then the idea of the bottleneck developed in that of a ‘tent’, in which the inclined walls would have been incurred each other, thus avoiding the need for an internal supporting structure.

Once again we can find in the description by Iannis Xenakis the best explanation of the composition procedure: “To choose one of the surfaces of the pavilion we proceeded more or less fixing the selected geometric curve in correspondence of a specific drawing. […] For this architecture in three dimensions the architect has to think not only in plan: he needs a three-dimensional representation as the elevations aren’t only the result of a parallel movement obtained by the orthogonal projections. The new heights of the three cusps have been chosen and their projections were determined on the horizontal plan, to increase the size of the central cone “L”. The first cusp was set at 21 meters above the ground, the second at 13 meters and the third at 18. Later, using both the experimental tool and the descriptive geometry, all the paraboloids were modeled, with the conditions that the intersection with the horizontal plan would conform the primitive scheme of the plan itself” (Xenakis 1958-59).

Figure 1
The Philips Pavilion at the 1958 Expo in Brussels.
The graphical tool becomes a device very useful to understand the work in the whole development, despite the difficulty of grasping the project in its spatial dimension. Tables and geometric diagrams with orthogonal, axonometric and perspective projections, alternate to make explicit the genesis and evolution of the morphology. In particular, the hyperbolic paraboloids are represented in the projective form making use of descriptive geometry, as to identify the development of each individual surface. From the analysis emerges, as will be confirmed by the digital restitution, that each element takes place also under the floor, and for this reason we decided to evaluate only the upper part of the surfaces, leaving out everything that stays under this plane. Although many graphical documents were destroyed, some of them are still available because they were published in the “Philips Technical Review”.

**GRAPHICAL MODELS OF SOUND**

In addiction to the genesis of the form we have to consider also the relation between architecture and music, that Xenakis was experimenting as a musical composer. In fact, he proposed a graphical method to describe the sound, particularly with his work “Metastasis” and thanks to the theoretical proposal of the Modulor created by Le Corbusier. It is not a coincidence that the architect himself, impressed by the hypothesis of the assistant, would include in the book Modulor 2 a text and two images describing the musical score by the composer. In the note Xenakis was very explicit: “In the composition ‘Les Metastasis’, for classical orchestra of 65 elements, the role of architecture is direct and fundamental thanks to the modulor. The Modulor found an application in the essence of the musical development. […] The six algebraic and temperate intervals of the range of twelve
sounds are emitted in times that are proportional to frequencies. [...] The sequence of temperate intervals is a geometric progression. The times will be the same. [...] On the other side, time has the additive property. A period can be added to another one and their sum is a period too. [...] Among all the geometric progressions, there is only one in which the terms have this additive property. It is the progression of the golden section. Here is how the idea of the Modulor created a close structure link between the time and the sounds” (Le Corbusier 1974). And in another text the composer explains the relation between Metastasis and the experience of the Philips Pavilion, above all in reference to the raising and lowering of the height of the sound, known to specialists with the term glissando: “If the glissandi are long and well intertwined, we could obtain some sound spaces in continue evolution. Among the possibilities, then, there is also that one that allows to arrive graphically (drawing the glissandi as some straight lines) to project some complex surfaces. I have done experience in Metastasis, the composition for orchestra which was executed in 1955 in Donaueschingen. Well, some years after, when the architect Le Corbusier, where I worked, asked me a proposal for the architecture of the Philips Pavilion in Bruxelles, my project was developed by the experience of Metastasis. So, I think in that occasion music and architecture found an intimate correspondence” (Xenakis 1962).

PHYSICAL SCALE MODELS OF THE PAVILION

A large number of models were realized by the authors to understand and verify the correctness of the morphology. The first ones were realized in wireframe structures, to describe the ruled surfaces themselves. They are very impressive because they represented in a simple way the complexity of the form and the articulation of the structure. Thanks to this abstract models it is possible to understand the generative procedure in every single step to transform the initial idea into the final solution.

Some others are at the same time important because they wanted to define the real opacity of the volume, with all the inclined walls in evidence. Then there were two particular models, the first one

Figure 4
Plan and perspective drawings about the final solution of the Pavilion.

Figure 5
Graphical representation of the musical composition ’Metasatsis’ by Xenakis.
After having analyzed every single document, such as pictures, drawings, texts, we started the geometric reconstruction of the Philips Pavilion, with a double finality: knowing better the procedure used to design the form, and realize a photorealistic model to explore it with a three-dimensional walk-through algorithm.

The first step was the realization of a series of simplified models to allow and understand better the real configuration of every single part. In particular the use of the color was very important to associate every element to the corresponding shape, so to identify single units in homogeneous way, and operate all the necessary deformations to obtain the final aspect of the model. After having identify the linear structure on which anchor the hyperbolic
paraboloids of the walls, we started the spatial geometrical reconstruction of every single paraboloid, drawing it in orthogonal projection. The complex grid allowed us to understand the three-dimensional parts that compose the Pavilion, confirming the extension of all the surfaces under the floor.

To verify the correct execution of the constructive operation we decided to slice the model in progression, both in plan and in elevation, in order to render totally visible the architectural space.

As a precise correspondence between the digital model and the graphical information from archives and publications was found, we developed further the representation to realize a photorealistic scene, using some algorithm of light simulation and texture mapping, and reconstructing all the main buildings of the area inside the Expo.

A SHORT DIGITAL VIDEO ON THE PAVILION
The last phase was dedicated to the creation of a video animation using digital technology. In this case the aim was to render the procedure of the composition of every single form from the beginning to the construction. The idea was to express directly and in an impressive way the relevant steps of the research, from the analysis of the geometry, transforming the flexible bands we talked about in the beginning into a digital representation, to reconstruct all the surfaces and to have a realistic simulation of the scene.

We defined a series of key-frames to realize some relevant sequences. In details we reproduced the sticks and the elastic bands of the tool used by Le Corbusier, and their continue movement until the position in which the single surface appears. Definitively, it was such as Le Corbusier’s hands were moving and searching the correct location for every element, but translated in digital form, adding all the parts that characterized the architecture itself (details, furniture, devices, etc.). The physicality of author’s hands were transformed in a set of digital frames, hiding the hands and making the sticks moving by themselves.

CONCLUSION
The research on the Philips Pavilion allowed to compare the difference between the traditional composition of this design, utilizing drawings and sketches but, above all, physical maquettes and the digital analysis made with new technologies, based upon...
Figure 10
Vertical sections of the digital model (elab. M. and M.S. Soraperra).

Figure 11
Photorealistic view of the digital model in the area (elab. M. and M.S. Soraperra).

Figure 12
Key-frames of the sequence of the video, describing the development of the form. (elab. M. and M.S. Soraperra).
digital reconstruction of abstract and figurative models.

The great use of scale models made by Le Corbusier and his assistants to verify and choose the best solution of the morphology, showed how a complex form could be realized without the utilization of digital instruments.

The possibility offered by the video to describe step by step the designing procedure has given an added value to the research, showing how the potentiality of the digital model stays not only in the formal registration of the volume of the architecture, but also in the development of the research itself.

The mixture between traditional methods and digital ones could offer the best solution to explore and understand an architecture in the best way.

NOTE
A part of this research was done during the graduation thesis of Michele Soraperra and Mery Simonetta Soraperra at the IUAV University of Venice, titled ‘Padiglione Philips (1958). Analisi della geometria configurativa e ricostruzione digitale’, Academic Year 2007-08, Supervisors Prof. Alberto Sdegno and Prof. Agostino De Rosa.

REFERENCES


