About the 'Cape'. Considerations on Geometries of the Maurizio Sacripanti's Osaka Pavilion Roof

Lorena Greco, Maria Laura Rossi, Marta Salvatore

Abstract

This study focuses on the interpretation of the shape of double curvature surfaces, which characterize the morphology of unrealized architectural projects, particularly interesting from the point of view of shape. The analysis of architecture, carried out by means of analogical instruments proper of the tradition of drawing, today finds a fruitful experimentation field in digital space and a privileged place for studying and validating the geometrical properties of architectural shape.
The experimented methodology faces the problem of reading architectural surfaces through the control of the respective geometrical properties in the field of continuous tridimensional representation in digital space. The object of the experimentation is the covering of the pavilion designed by Maurizio Sacripanti for the Universal Exposition of Osaka in 1970. It is an emblematic case because of the different interpretations to which the drawings of the 'cape' are susceptible.
Moreover, the interest for this work regards both the geometrical shape of the roof and the idea of movement, which becomes the backbone of a kinetic architecture that transforms technology into architectural language.

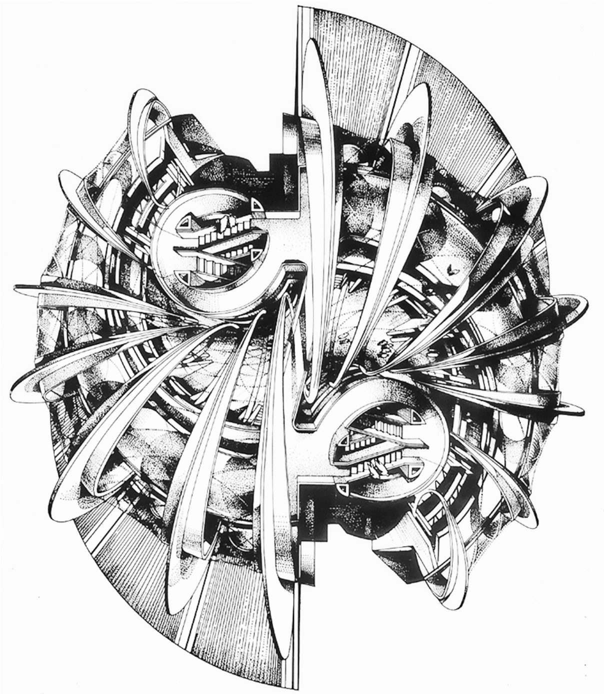
Keyword: Maurizio Sacripanti, Italian pavilion, Osaka, cape, kinetic architecture.

Introduction

This study gives attention to the interpretation of the shape of double curvature surfaces that characterize the morphology of unrealized architectural projects.
The analysis of the architecture, which, in the drawing tradition, was conducted by analogical means, i.e. graphically, today finds fertile experimentation in digital space as a privileged place of study and validation of geometrical properties of the shapes of which the architecture is made. 3D modeling had the great merit of allowing the materialization, in digital space, of mental processes of imagination and control of the shape through virtual construction of the models. Gino Loria, in the early nineteenth century, argued that construction is the existential demonstration of shape, and today, as never before, this consideration is topical in relation to the virtual space of a computer [Loria 1935, p. 276]. Today, we can operate directly in space, making use of curves and surfaces with double curvatures towards the solution of problems related to the control of shape. In geometry, in recent years, this operativity amplified the field of experimentation including more and more complex constructions in the classical repertory of problems solvable through a synthetic method, namely through the drawing.
The research of the geometric shape finds fruitful field of experimentation in the architectural design domain, where the properties of lines and surfaces become a design opportunity. At the same time, this research finds a further field of application in the critical reading of unrealized

architectural projects, where the identity of the architectural shape is the result of the coherence between its geometric characteristics and its graphic representation.
Sometimes it happens that this congruence is not found. Consequently, this critical reading reveals some ambiguities. This is the case of the roof of the Italian Pavilion that Maurizio Sacripanti designed for the Osaka Universal Exposition of 1970, emblematic because of the different interpretations of which the representations of the 'cape' are susceptible (fig. 1).
The Osaka pavilion is one of the 'kinetic architectures' that Sacripanti designed in the Sixties. Conceived as living organisms, they present particularly articulated spaces, characterized by a certain formal complexity and a marked plasticity.

Fig. 1. Sacripanti Studio, Osaka pavillon perpective, Rome, Accademia Nazionale di San Luca, Archivio del Moderno e del Contemporaneo. Fondo Maurizio Sacripanti. 1968 - Progetto per il Padiglione italiano all'Esposizione Universale Expo '70 a Osaka, n. 11/34. <http://www.fondosacripanti.org/elementi_online.php?id=42>.



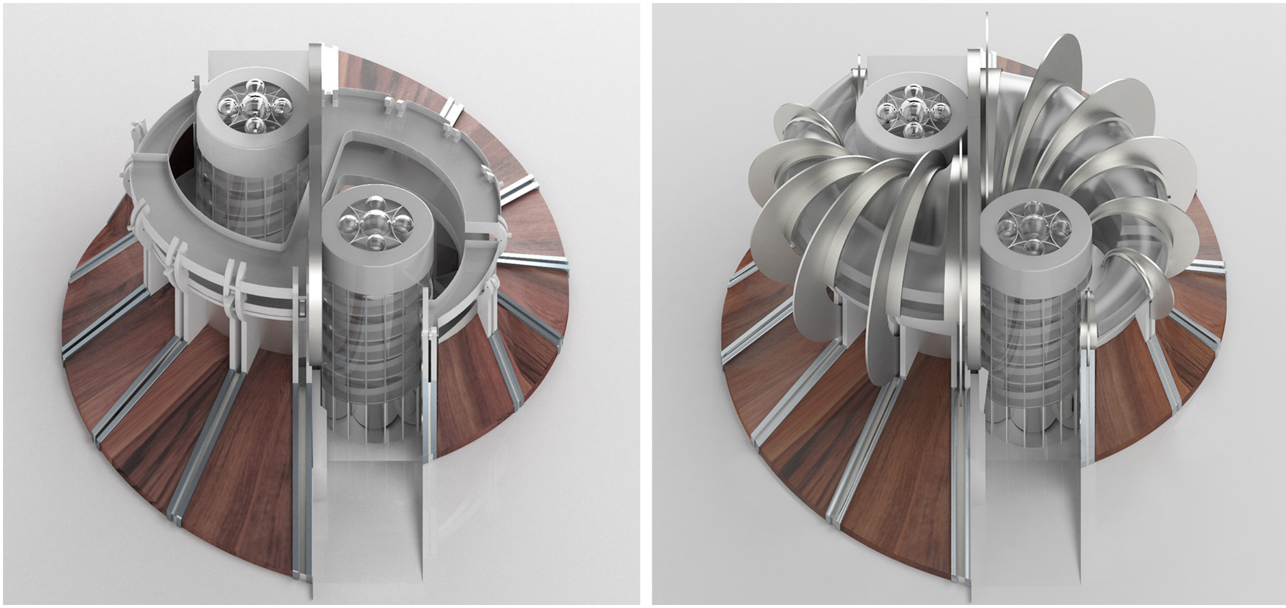
This complexity is not found in the properties of the singular surfaces used; rather it is found through a combination of a set of simple geometries designed, considering 'time' as part of the project from which mechanical variable spaces come to life, animated by movement.
The interest in this work lies in the geometric conformation of the 'cape', as well as in its compatibility with the idea of movement, the driving element of this architecture. A critical reading of the graphical and physical models that came to us reveals some ambiguities. These were the starting point for a series of reflections into the research of a shape as geometric locus, according to the idea at the basis of the architectural project and with the movement of the structure.
Therefore, the 'cape' of Osaka was an opportunity to experiment a methodology aimed at the morphological analysis of architectural surfaces characterized by a particular formal interest, through a process of geometric rationalization that operates in the context of continuous tridimensional representation [1].

The reasons for the 'cape'

The "variability of shapes" and the "changeability of space" [2] are indeed themes that Sacripanti investigated and developed starting from the early sixties, beginning with the design for the Peugeot Skyscraper facing, composed of movable panels, to the structure of the project for the Lyric Theater of Cagliari, inspired by the scenic representation of John Cage's ballets [3]. However, it is in the proposal of the Osaka Pavilion that movement becomes a key element of kinetic architecture, inspired by programmed art that makes technology as a design instrument, transforming it into architectural language.
Conceived as a dynamic expository path, the pavilion is formed by two equal parts, each symmetrical and upside down with respect to the other, composed of two "curved and empty truncated cones reminiscent of each other in their increasing and decreasing trend" [4]. Each of these parts is made by a static structure, a dynamic structure connected to the first one and a membrane system that Sacripanti defines as 'cape' in the technique report (fig. 2).
The fixed core identifies the static scheme of the pavilion and includes the expositive curved walkways; two cylindrical bodies enclose the helicoidal staircases and the installation channels.

Fourteen vertical steel structures are connected to the two towers. These elements are coupled easels that support two series of seven circular-shaped movable metal disks decreasing in diameter, which are tangential to the cylindrical pillars of the staircases.
These disks, independent among themselves, would move rotating around an eccentric center, in their planes, each with its own oscillation, between 0 to 18° for the sixth and seventh disks, and 15° for the other five [5] (fig. 3).
The expositive path would be covered by a membrane, the cape, "very difficult to draw and represent" [Sacripanti 1969, p. 2].
The image of the cape must have been clear to Sacripanti when he drew up the design report: "space and volume are together broken up and rebuilt in the project" [Sacripanti 1973, p. 90]. Thus, the static image of "curved and empty truncated cones" is broken by movement, which transforms the architecture into a place of absolute formal unpredictability, in which the living space is constantly modified by an "infinite combination of the movement of the blades" [6]. This changeability, produced by the introduction of time, and therefore of movement as a design element, had to be amplified by a transparent and iridescent plastic cover, which would have produced ever-changing light effects with each pulsation of the membranes.
Concerning the manner for supporting these membranes, the documents that came to us show different ideas. Thus, the sketches and project drawings, the physical models and the written and verbal testimonies of those who had collaborated with Sacripanti in the architectural project, show a certain ambiguity of interpretation, which affects both the overall shape of the cape and the shape of its support structure.
In the design report, Sacripanti describes: "reinforcing wings perpendicular to the motion plane that carry transparent plastic membranes, whose figurative weaving will be characterized according to a scheme already in development by one of the greatest Italian painters" [7]. We are not sure who was the painter appointed for the design of the 'cape', but the idea of a semi-rigid connection structure between consecutive disks can be found in some of the design sketches [8] (fig. 4).

Fig. 2. Digital reconstruction of the static structure (on the left) and dynamic structure (on the right) of the pavilion.



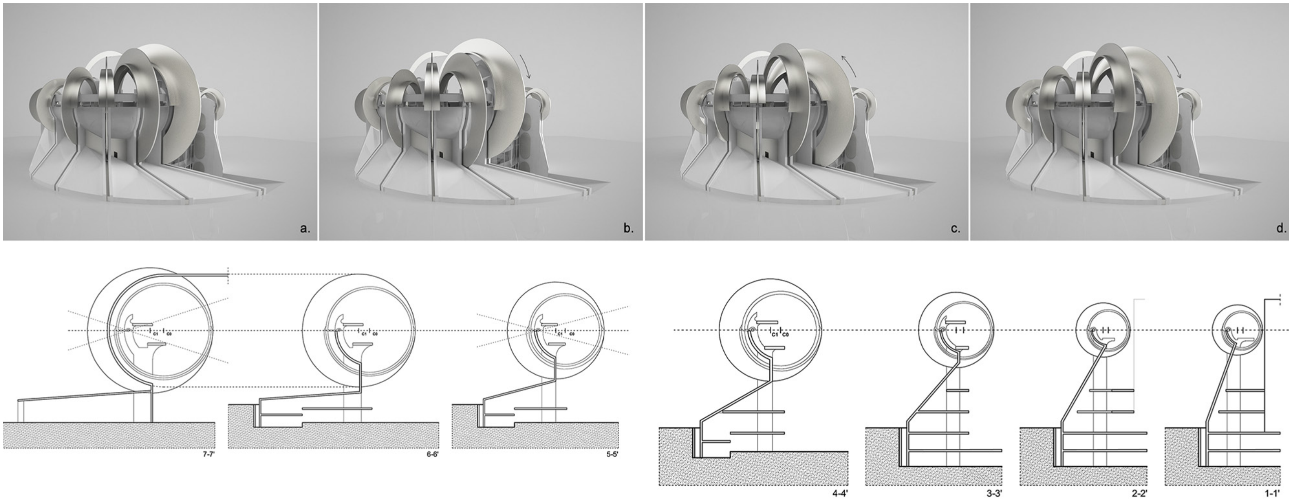


Fig. 3. Digital reconstruction of dynamic structure of the pavilion in the phases of the disks movement, based on design drawings.

Instead, we know that the roof of the pavilion was introduced at the end of the design process and widely debated in Sacripanti's studio because, as Franco Purini recounts, it was necessary to "think about the shell because, when it rains, there was the problem of how to cover it" [9]. Purini describes how a metal network would have to sustain the cape, conceived as a 'dress', placed on a movable structure, an idea that is reflected in the model and in some competitive drawings (fig. 5).
The same competitive tables, in which the net between one disk and the next is represented, do not provide univocal information about the shape of the cape. In fact, the convexity of the 'cape' seen in the plan is not coherent with the concavity of the net represented in elevation.
The changeability of the project must have characterized it also in its first creative phases. Some sketches seem to reflect this idea, as confirmed also by Achille Perilli in his *Testimony* about the entire design process of the pavilion [10]. These reflections were the starting point for some geometric speculation researching a rational form of the cape. The goal is to find, through the geometric digital construction of the surfaces, the reasons for a form that does not have only one definition in the different representations of the project.

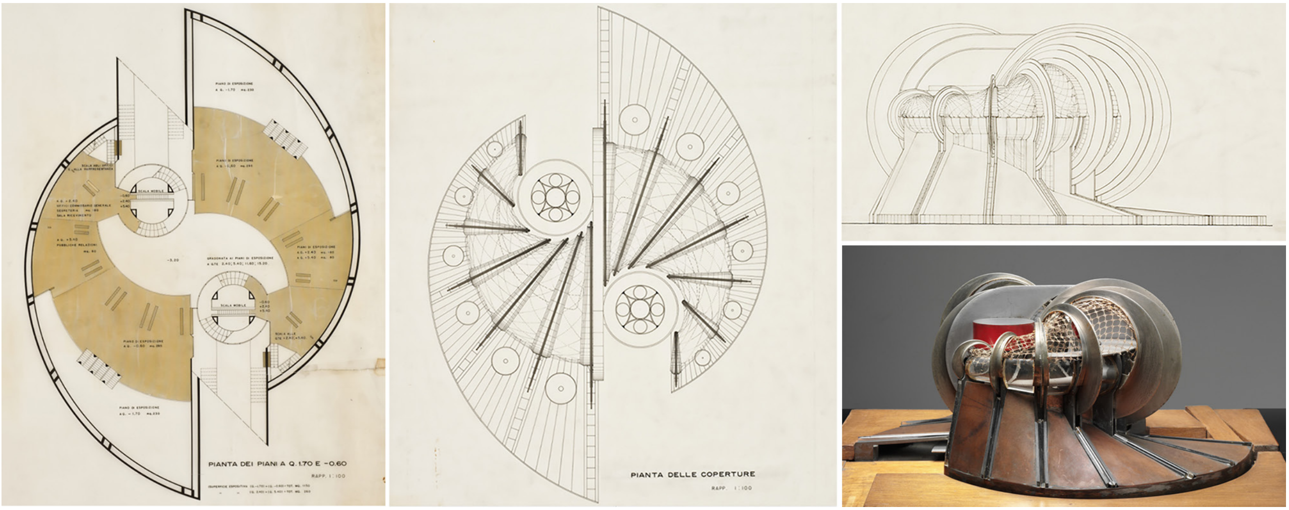
The research of the form

A reading of the 'cape' drawings, mostly preserved at the *Fondo Sacripanti* at the Accademia di San Luca and at the

Fig. 4. Sketch of Osaka pavilion, MAXXI Museo nazionale delle arti del XXI secolo, Rome. MAXXI Architettura Collection, Maurizio Sacripanti Archive, n. F10252.

Collection of XX Century at the MAXXI in Rome, reveals a continuously evolving form, variable since the early stages of its design process.
The incisive and suggestive images of "curved and empty truncated cones" [11] recall two opposed and rotating parts of a Dupin cyclide [12], a surface that has the appearance of a torus with variable, increasing and decreasing sections. The shape of this surface, that finds application in the design field, is generally known and part of the common visual experience, although its properties are not well known in architecture.
The image of a Dupin cyclide occurs in some design sketches and let us hypothesize that this geometry may have inspired, perhaps from its preliminary phases, the idea behind the shape of the 'cape' (fig 6).
However, the geometrical characteristics of this surface are not compatible with the disposition of the circular blades. In fact, a Dupin cyclide is the locus of circumferences passing through the contact points of a mobile sphere tangent to three given spheres and, like all cyclides, admits only circumferences for curvature lines [13] [Dupin 1822, p. 336; Hachette 1813, p. 442]. Given this surface, it is possible to obtain two series of curvature lines by sectioning them with two groups of planes, one for each series. These planes have as support axes, respectively: the axis of the surface; the straight line intersection between a pair of planes passing through two sets of three contact points between the mobile sphere and the three given spheres (fig. 7).
All other planes intersect the surface according to a fourth order curve, eventually according to two curves of a lower order, but not according to circumferences.
The Dupin cyclide is compatible with the planimetric layout of the project, in particular with its apparent contour, represented in the design of the plan by two eccentric circumferences. However, this interpretation is not coherent with the circular geometry of the metal disks. In fact, the planes of the disks, although they are parallel to the axis of the surface, do not pass through its center, and therefore cannot intersect it according to the circumferences. It follows that if this were a Dupin cyclide, the disks could not be circular and the approximation would be greater as the surface decreases (fig. 8). It is possible, as mentioned above, to hypothesize that the generative principle of the 'cape' shape may have been inspired by this surface, as the sketch

Fig. 5. Project drawings, Rome, Accademia Nazionale di San Luca, Archivio del Moderno e del Contemporaneo. Fondo Maurizio Sacripanti. 1968 - Progetto per il Padiglione italiano all'Esposizione Universale Expo '70 a Osaka, n. 2, 4, 6/34, <http://www.fondosacripanti.org/elementi_online.php?id=42>; architectural model, MAXXI Museo nazionale delle arti del XXI secolo, Rome. MAXXI Architettura Collection, Maurizio Sacripanti Archive, n. MOD43.



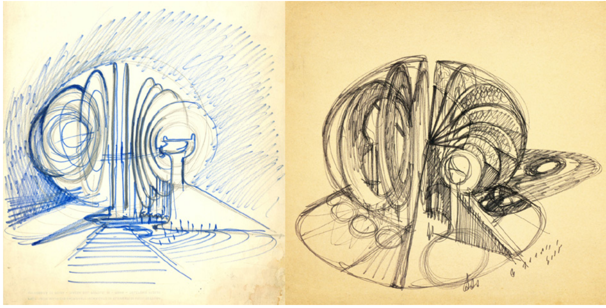
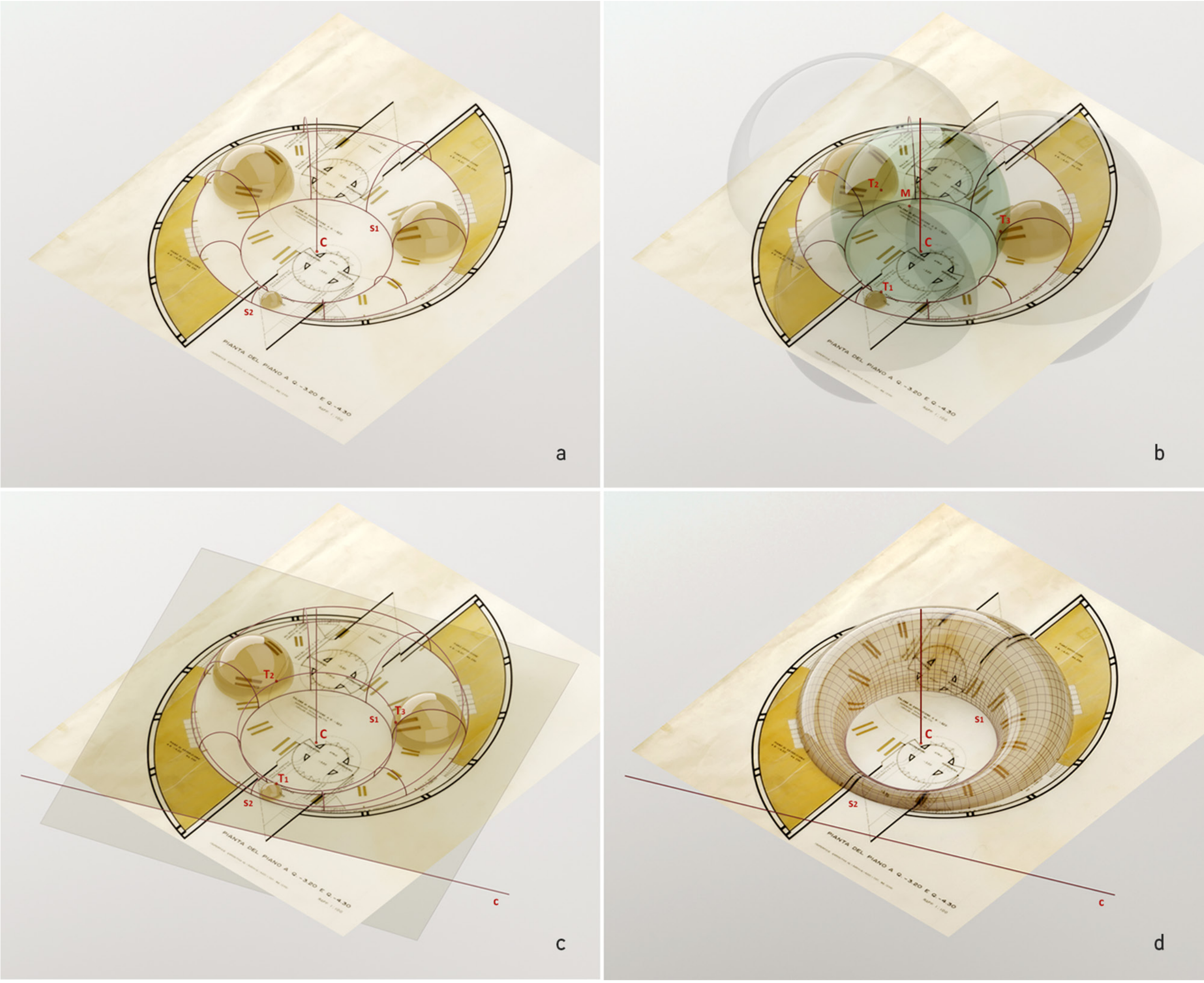


Fig. 6. Sketches of the Osaka pavilion by Sacripanti studio, MAXXI Museo nazionale delle arti del XXI secolo, Rome. MAXXI Architettura Collection, Maurizio Sacripanti Archive, n. 32462, 32464.

in figure 6 would seem to indicate, in which the planes of the moving circles pass through the center of the surface.
The construction of a Dupin cyclide is rather laborious if executed with graphical methods of representation on the plane. Today it is possible to represent this surface with accuracy directly in the digital space starting from their properties, and therefore from the construction of some of the circumferences that form its series of curvature lines [14].
Thus, in the case of Osaka, it was possible to construct this surface starting from the apparent contour of the cape seen in the plan, namely, from a pair of eccentric circumferences that are curvature lines of the first series, which are placed on the symmetrical plane of the surface. The second series of the curvature lines is easily constructed by cutting the assigned pair of curvature lines with the planes which have the axis of the surface as a supporting straight line. In this manner we obtain the pairs of points placed on the outer and inner curves. They are then placed at the extremes of the diameters of the circumferences that describe the second series of curvature lines. The construction of the first series consists of using a mobile sphere with a variable radius which, once in motion, envelopes three given spheres. The three spheres in question are inscribed in the eccentric circumferences of the cape of the pavilion seen in the plan. We establish two configuration types of the movable sphere, which represent two of the infinite positions that this sphere can assume in motion, and which determine two triads of contact points between this moving sphere and the three given spheres. Each of these groups of three points defines a curvature line and a plane that belong to it. The straight line, intersection of the two planes thus obtained, is a support for the group of planes which section the cyclide according to the first series of curvature lines, which is thus determined (fig. 9).
Although there are certain formal relationships between a Dupin cyclide and the cape form, this surface is in no way deformable, and is therefore incompatible with disk movement and consequently with the kinetic requirements of the project.
In order to obtain a shape for the cape compatible with the movement of the structure, it is possible to imagine the membrane as a set of surfaces stretched between adjacent disks.
If, in the case of the cyclide, the surface is suggested by the planimetric drawing, in this second experiment the interpretation is indicated by the elevations. Indeed, the concavity of the cape in elevation would be satisfied by the elasticity of the membrane, which would, however, also characterize the design of the plan. Among the geometric locus surfaces which can satisfy the movement of the structure and the concavity of the membrane, ruled surfaces were considered, whose images are suggested by some design sketches (figs. 4-10).
It is possible to imagine the ruled surfaces whose generatrices, placed between two movable neighboring circles, are elastic or extensible, such as for example a telescopic shaft, which would be compatible with the description of the wings described by Sacripanti in the design report.
Using these ruled surfaces, the rotation of the disks would produce a torsion of the surfaces, extending or contracting the extensible generatrices, while maintaining unchanged their geometric properties. A well-known demonstration given by Monge on ruled surfaces demonstrates how these surfaces are thus defined, when they lean on three directrices [Fallavollita 2009, p. 154, 155]. If these three directrices are curved, the ruled surface is generic. Various types of ruled surfaces, having a different form and a different disposition of their generatrices, can pass through two circumferences generically oriented in space. In the case of a transparent membrane, the disposition of the generatrices conditions the overall image of the project. Imagining the support structure of the membrane as a ruled generic surface would guarantee a division of the disks in equal parts, through which the extensible generatrices of the surface pass (fig. 11).

Fig. 7. Construction algorithm of a Dupin cyclide on the planimetric representation of the pavilion.



Therefore, it is possible to experiment further configurations and hypothesize that the surface leans on two mobile circles and one straight line, which, for example can be reconstructed according to the design traces. In the case in question the straight line passes through the centers of two contiguous disks, the ruled surface is a cylindroid, and the generatrices divide the disks in irregular intervals at a progressive increase (fig. 12).
It is possible to go further, conjecturing that the movable discs were circular sections of an elliptical one-sheet hyperboloid. In this case, the generatrices of the ruled surface would meet the circles of the disks at regular and symmetrical intervals, although different among themselves. It is then possible, within the continuous tridimensional drawing, to represent the disks and the cape by writing of one's generative algorithm. Thus, it would be possible to simulate, in a parametric environment, the movement of the structure, as additional verification of the validity of the formulated hypothesis. Moreover, this kind of algorithm would allow experimentation of the use of minimal surfaces, which would convincingly approximate Sacripanti's original idea [15].

Conclusions

As it was possible to foresee, the experimentation conducted, did not identify a geometric locus form able to contextually satisfy all the obligatory conditions of the project and the movement idea of the structure. The cape was introduced in the final phase of the project due to functional exigencies. Therefore, it is possible to hypothesize

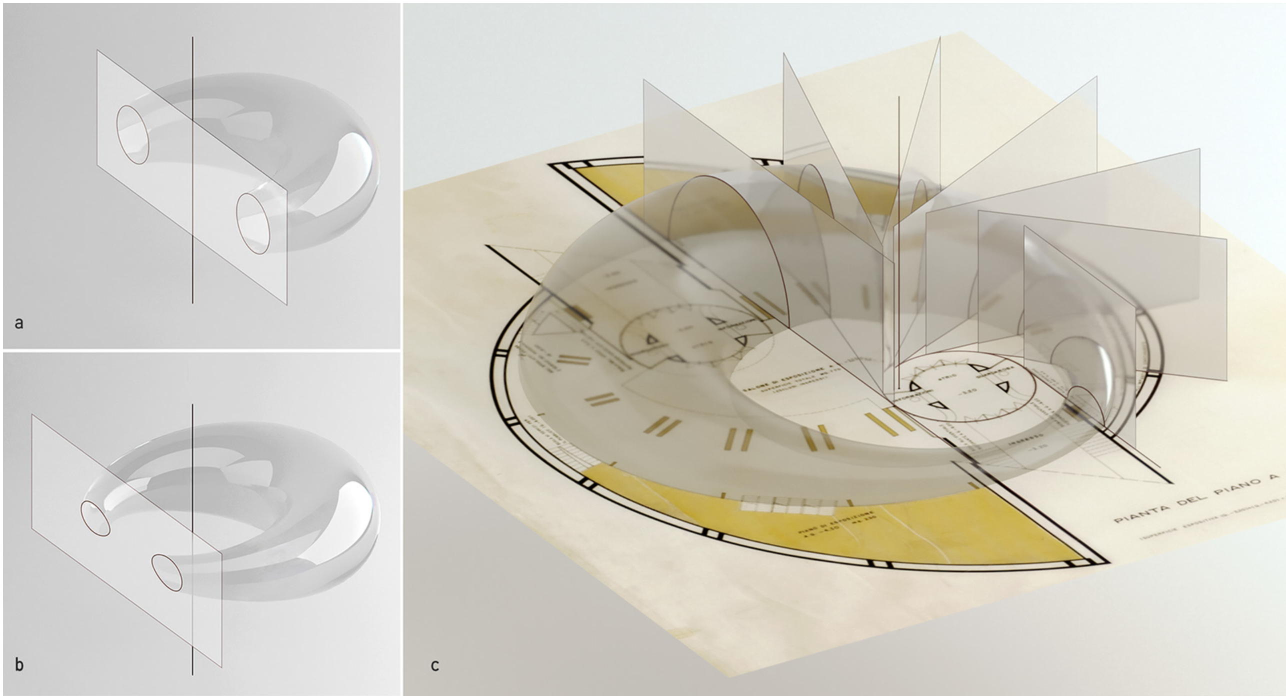
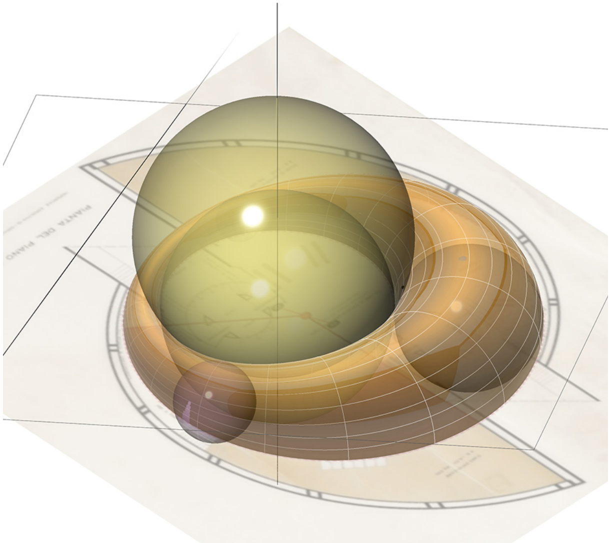


Fig. 8. Sections of a Dupin cyclide obtained by the planes passing through the axis (a), parallel to this axis (b) and by the pavilion blades (c).

Fig. 9. Geometric genesis of Dupin cyclide starting with its two series of curvature lines.



that, at the time of competition, a clear image of a plastic and iridescent membrane had not yet found an univocal geometric definition. Thus, the drawing of the 'cape' would have communicated, through the image of pulsating membranes, the metaphor of a country in movement despite the difficulties, deferring the problem of the form of the cape to a subsequent phase.

If, on the one hand, this visionary architecture transmitted a symbolic message, on the other, it concretely tested technology, according to a constructive approach characteristic of Sacripanti's projects: "In architecture […] it is necessary to use 'pure thought' through all the pitfalls of reality and various necessities, because people come into the architecture that we create…in this sense it is one of the most difficult arts, otherwise architecture would be like music… Isn't that right? Hence, one invents technique himself. Therefore, technique also becomes a poetic occasion. Every painter has his own technique" [16].

We can therefore imagine that formal definition of the cape, was not found in the competition phases would have been resolved in that constructive phase that never saw the light. Perhaps, in that phase, the architecture would still have been modified, proceeding in a continuous evolution which characterized it from its inception [17].

Fig. 10. Digital reconstruction of the ruled surface and sketch of the Osaka pavilion by Sacripanti studio. MAXXI Museo nazionale delle arti del XXI secolo, Rome. MAXXI Architettura Collection, Maurizio Sacripanti Archive, n. 32465.

Fig. 11. Genesis of the cape as a generic ruled surface and simulation of the movement.

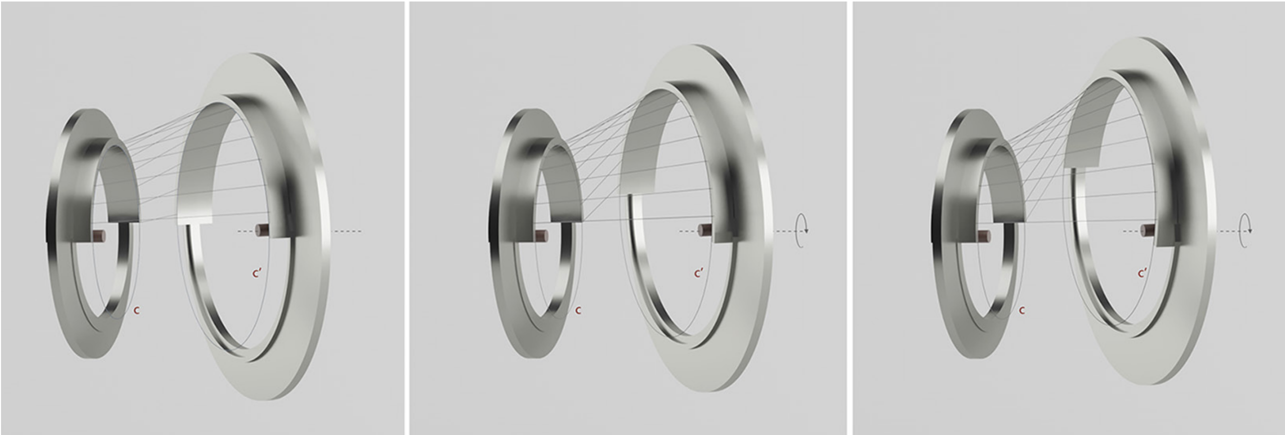
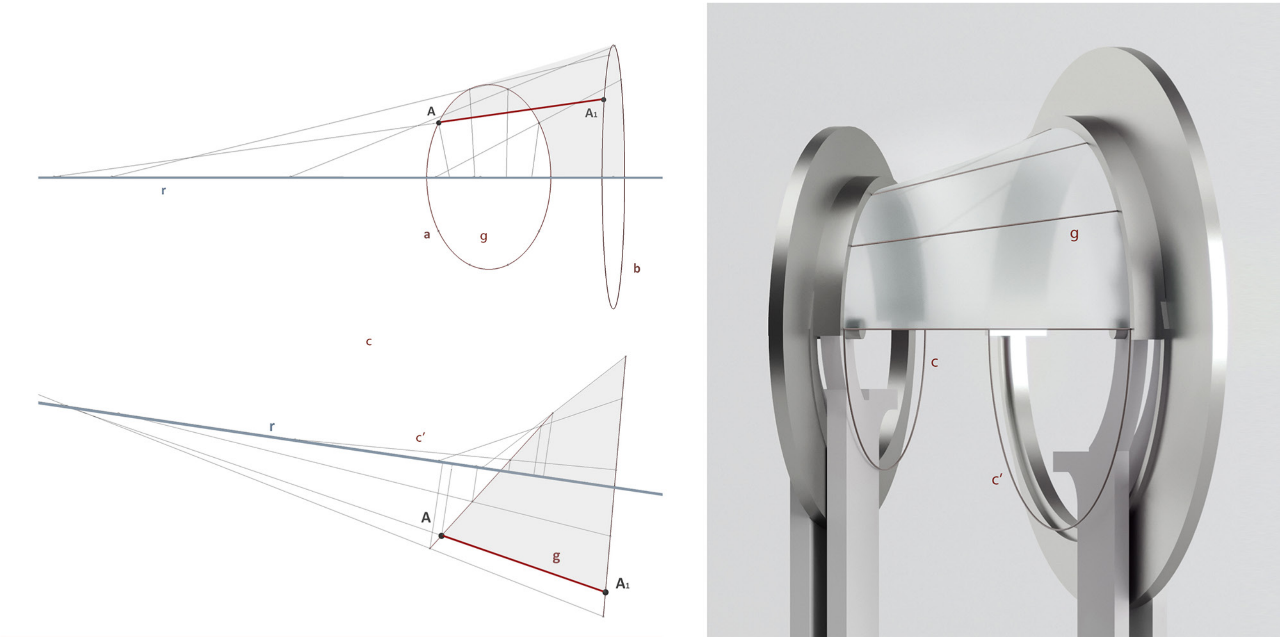


Fig. 12. Genesis of the cape as a cylindroid.



"Maybe the country does not move", Renato Pedio comments in the pages of *L'architettura, cronache e storia* regarding the Osaka pavilion [Pedio 1969, p. 55]. Notwithstanding the transitory nature of the Expo and the technological capabilities of the host country, the project did not continue. Thus, nothing remains of the cape except for the drawings which, even today, communicate the force of an idea.

The authors shared the contents and the critical analyzes conducted in this study. In particular, Marta Salvatore dealt with the coordination and the methodology, Lorena Greco the historical aspects, the experimentation on the ruled surfaces and the digital images elaboration, Maria Laura Rossi the experimentation on the cyclids.

Notes

[1] The control of the geometrical properties of the form in this study was conducted through the NURBS mathematic which, as is known, describes lines and surfaces in space, in a continuous way, through mathematical equations of a parametric type.

[2] See: Sacripanti, M. Progetto per il nuovo Teatro lirico, Cagliari. In Neri, Thermes 1998, p. 60.

[3] "At the last biennial a Cage ballet was represented with scenes and costumes by Rauschenberg. I remember well the stimulating show and the unappealing scenography accompanied my memory. The Cagliari competition was an occasion to overcome old disappointments […]": Neri, Thermes 1998, p. 60.

[4] This way, Sacripanti describes the idea at the basis of the cape in the technical report of the project: Sacripanti, M. Progetto per il padiglione italiano alla Esposizione Internazionale - Expo 70, Osaka (Giappone). In Neri, Thermes 1998, p. 117.

[5] Sacripanti, together with Eng. Maurizio Decina, thought up a computerized programming of movement. They designed a compressed air pneumatic mechanism for the propulsion and automatic control of moving structures. These structures are activated through programmed movements, according to pre-established temporal sequences, recorded in code on perforated tapes, decoded by a special reader. Sacripanti used a technique, as Decina recounts in his *Testimony* available through the Fondo Sacripanti at Accademia di San Luca Archive, by which he was particularly fascinated. The functioning of the mechanism is amply described in the design report: Sacripanti, M. Progetto per il padiglione italiano alla Esposizione Internazionale - Expo 70, Osaka (Giappone). In Neri, Thermes 1998, pp. 118-120.

[6] In the motion each of the blades would follow an own oscillation. This independence would have differentiated the dynamic movement of architecture from the repetitive and serial characteristic of mechanical components, such as pistons or connecting rods, from which this explicitly took the distances: Sacripanti 1973, p. 90.

[7] The technical report does not have specific information about the shape and size of the wings: the same indication concerning their arrangement is ambiguous, since the motion plans are different for each blade: Sacripanti, M. Progetto per il padiglione italiano alla Esposizione Internazionale - Expo 70, Osaka (Giappone). In Neri, Thermes 1998, p. 115.

[8] Achille Perilli collaborated on the Osaka project. It is possible that Sacripanti referred to him in the design report, although Perilli declares that he had worked only a little on the project, because of the many changes made in his design process. See the interview with Achille Perilli in *Testimonianze*, Accademia di San Luca Archive, Fondo Sacripanti. <http://www.fondosacripanti.org/testimonianze.php> (accessed 2018, March 21).

[9] See the interview with Franco Purini in *Testimonianze*, Accademia di San Luca Archive, Fondo Sacripanti. <http://www.fondosacripanti.org/testimonianze.php>(accessed 2018, March 21).

[10] See the interview with Achille Perilli in *Testimonianze*, Accademia di San Luca Archive, Fondo Sacripanti. <http://www.fondosacripanti.org/testimonianze.php> (accessed 2018, March 21).

[11] See the project report in: Sacripanti, M., Progetto per il padiglione italiano alla Esposizione Internazionale - Expo 70, Osaka (Giappone). In Neri, Thermes 1998, p. 117.

[12] Dupin's cyclide owes its name to Charles Dupin, a pupil of Gaspard Monge who, in the second half of the nineteenth century, first defined the properties of this surface.

[13] The curvature lines cover the surface without gaps, forming two series of curves orthogonal to each other, which indicate, in each point, the direction of the main curvatures of the surface.

[14] It is possible to construct a Dupin's cyclid in the digital space by enveloping its curvature lines. The greater the number of lines of curvature lines, the better the approximation.

[15] A minimal surface disposed between two skew disks would assume the form of a soap foil, obtained by imagining immersion of the structure of the blades in a soapy solution.

[16] See the interview with Sacripanti titled *Maurizio Sacripanti | "Più di questo non so dirvi …"*, 1989, by Luca Ciancarelli and Gaia Remiddi, in "Interviste", Department of History, Representation and Restoration of Architecture (ArchiDiAP), Sapienza University of Rome website: <http://www.archidiap.com/intervista/piu-di-questo-non-so-dirvi-maurizio-sacripanti/> (accessed 2018, March 21).

[17] Renato Pedio recounts that Sacripanti would have modified the symmetry of the pavilion if the project had gone ahead: Pedio R. Per Maurizio Sacripanti. In Giancotti et al. 1997, p. 22.

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