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# Between Memory and Innovation: Algorithmic Analysis of Some Catoptric Anamorphoses by Jean François Nicéron

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**Abstract.** Descriptive Geometry forms the foundation of the science of representation, and has supported designers, engineers, architects and artists throughout the centuries. Its understanding has provided the basis to control three-dimensional shapes in space and their reproduction through recognizable bi-dimensional images. In this paper an extreme case of representation will be discussed, the intriguing and infallible technique of *Anamorphosis.* This is a form of representation that takes advantage of linear perspective in order to achieve a distorted and disrupted image, or three-dimensional configuration, which appears as a regular form only when it is observed from a specific point in space, or with the aid of mediating devices, displaying a figure which was previously unrecognizable. Known empirically from the beginning of the sixteenth century, Jean François Nicéron was the catalyst of this topic.
The most challenging aim of the underlying research is the identification of an algorithmic digital system able to automatically generate this type of representation.

*Key Words:* algorithm, anamorphosis, catoptric, computational design, Descriptive Geometry, illusionary perspective

*MSC 2010:* 51N05, 68U07, 01A45

## 1. Introduction

*Anamorphosis* is a geometrical procedure that creates a single unique viewpoint where an image is depicted with natural proportions, while all other points of view give the impression of a distorted form. According to Jurgis Baltrŭsaitis [1] this is *"the demonstration of the uncertainty of sight, a revelation of the extraordinary aspects of nature"*.

Anamorphosis can be classified in *optic and catoptric*, based on the process in which the image has undergone. According to this definition, the former is known as *direct*, since the image appears correct, simply if it is seen from the viewer eyes (Figure 1). The latter, instead,

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Figure 1: Example of an anamorphic fresco of the Gallery of Trinità dei Monti monastery in Rome by Emmanuel MAIGNAN, 1642. The figure shows the deformed image that appears when walking through the corridor (reproduced with kind permission of Bibliotheca Hertziana).

is called *indirect* because the process requires a mediating device, such as a mirrored surface, to reveal the illusion.

A conical or cylindrical 'mirror' is generally placed on a surface, where a deformed image is drawn all around it. By looking from the specific point del'oeil[1], established from the artist, the mirrored entity transforms the flat and disrupted image into a clear and regular picture (Figure 2). This discovery is possible through a wise use of the laws of reflection in the definition of the deformed image.

Known empirically from the beginning of the sixteenth century, initially in reference to magical connotations and its illusionistic power, the *'magia anamorphotica'*, as defined by Gaspar SCHOTT [10], became a substantiated scientific topic in the seventeenth century. As implied by the title, the study is focused on Jean François NICÉRON's treatise *'La perspective curieuse ... '* [9]. He was the catalyst of this field and his treatise is considered to be the scientific cornerstone of the anamorphic knowledge.

The fascination of Anamorphosis comes from its conflicting nature: the bond between the astonishing and illusionary features of representation and the mathematical rigor of its geometrical techniques. My interest in this hidden aspect of classical perspective comes from the will to understand the role played by the combination of art and science in the definition of Anamorphosis, as well as to prove the importance of the interaction between the classical procedures of Descriptive Geometry and modern techniques of Computational Design, in search for a new language of representation in connection with a deeper spatial consciousness, sometimes taken for granted in our virtual era.

The research has been conducted, with a comparative methodology: the analytic studies,

[1] *Point del'oeil* is a vernacular french term, used by Jean François NICÉRON 1638 in [9]. The literal translation of the term is 'point of the eye'; but it is better interpreted as 'point of view'. Furthermore, this terminology inspired the title of my master thesis *"Point del'oeil, l'anamorfosi di Jean François Nicéron, tra spazio e immagine"*, Supervisor: Luigi COCCHIARELLA, graduation date: 26/04/2016

Figure 2: Example of a catoptric Anamorphosis on a mirroring cylindrical surface by Jean François NICÉRON, 1635, *Ritratto di Luigi XIII*, Roma, Palazzo Barberini (per gentile concessione delle Gallerie Nazionali di Arte Antica di Roma: Palazzo Barberini. Foto di Mauro COEN).

undertaken on the historical procedures, have been reexamined and translated onto the digital platform in order to control the geometrical operation in the space. The virtual reproduction of the system exalts the spatial operation of Descriptive Geometry, enhancing the technical awareness of its procedures.

The potential of this study, that provides a synthesis of the research conducted during my master thesis at the Politecnico di Milano, lies in the interdisciplinary approach to the subject; the interconnection of the theoretical principles of Descriptive Geometry and a virtual environment is the key to revitalize the language of representation and to strengthen interest in it. My contribution provides a vivid demonstration of the importance in gaining a level of up-to-date representational awareness that is open and integrated with the theories and discoveries from the past, and, at the same time, able to take advantage, in a conscious way, of the technical developments available today.

The paper is structured in two main sections. The first section focuses on the evolution of anamorphic techniques, from its identification to the point where its geometrical rigor was defined. The second one demonstrates the potential of managing the historical geometrical process in a three-dimensional environment, through the use of parametric solutions, in order to achieve a virtual re-creation of the anamorphic procedures. The paper will conclude regarding some considerations on the potentials of this method and its possible application in modern architecture.

Finally we want to emphasize that many other aspects of Anamorphosis and of NICÉRON's work can already be found in the literature (see, e.g., [2, 3, 4, 5, 6, 7]).

## 2. Anamorphosis between magic and scientific rigor

The knowledge behind anamorphic procedures has been the subject of technical investigation for more than two decades. Although their bond with the perspective experience has already

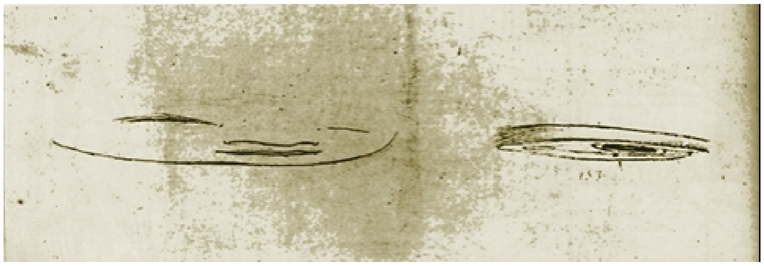

Figure 3: The first anamorphic drawings by Leonardo da Vinci, *Codex Atlanticus* (1483–1515) (Milano, Biblioteca Ambrosiana).

been foreseen from the fifteenth century, by Leonardo da Vinci first, Albrecht Dürer and subsequently Daniele Barbaro, the final definition of its principles was preceded by a long figurative approach that involved artists and painters in its empirical use. Leonardo da Vinci was the first one to give a scientific slant to the anamorphic matter; in his *Codex Atlanticus* (approx. 1515) we can find traces of the most ancient anamorphic drawings yet discovered: a child's face and an eye (Figure 3). Although the first attempts in this approach came from Italy, where studies on the theoretical foundation of perspective have been active since the beginning of the fifteenth century, the field test of this representational technique was developed in northern Europe, where Anamorphosis was not only considered as simple curiosity but a work of art able to reveal, to an expert eye, its deeper political, religious and erotic secrets.

A pupil of Albrecht Dürer, Erhard Schön (1491–1542), was the most active artist in this bizarre form of representation. These tricks of the eye were known as *Vexierbild*, which means 'painting with secret'. An example is the anamorphic portrait of Ferdinando I,

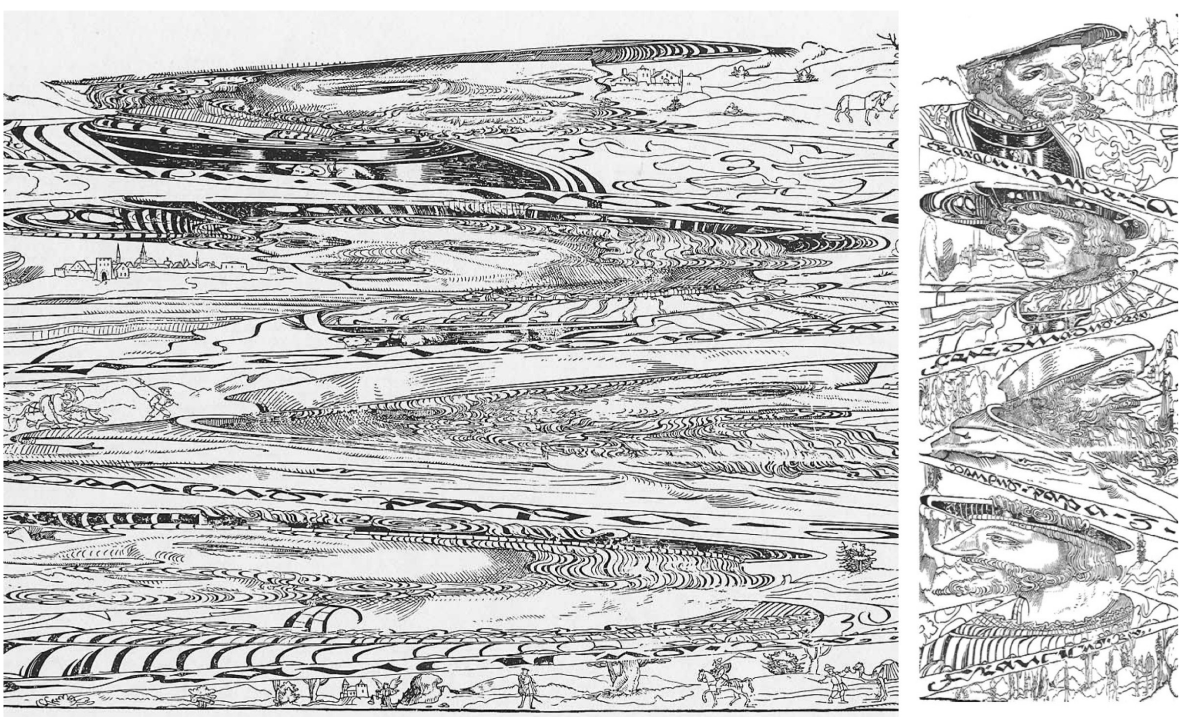

Figure 4: Anamorphic drawing by E. Schön: *Vexierbild mit vier Porträts*; on the right rectified image, 1535 (J. Baltrŭsaitis [1]).

Francesco I, Carlo V and Pope Paolo III (1535), whose faces are apparently absorbed in an incomprehensible tangle of lines, until the eye gets closer to the canvas; only in that moment the mystery is revealed (Figure 4).

In order to achieve an astonishing illusionistic effect the painter had to undergo mechanical procedures to transfer the original image to the wall, opportunely deformed to be seen from a specific point of view.

Hans Holbein the Younger experienced the use of anamorphic figures, beyond the simply entertaining purpose, for the first time in 1533. In its painting *The Ambassadors*[2], a deformed image is hidden in an apparently normal perspective scene. A skull is revealed to the viewer only when one gets further from the image and takes a last glimpse

Despite the artistic proliferation of the anamorphic technique, its use remained circumscribed to the practical sphere rather than to the definition of its geometrical rules. The first attempt to define a scientific consistency to the contemporary anamorphic work was found in the treatise *Le due regole della prospettiva pratica* (1583), written by Jacopo Barozzi da Vignola with the geometrical support of Egnazio Danti. His technical solution to the anamorphic issue was based on an arbitrary extension of the image enclosed in a grid (Figure 5). Although his technique seems to move in the right direction, towards the definition of the anamorphic laws, it fails to consider a specific point of view from which the illusion should be revealed.

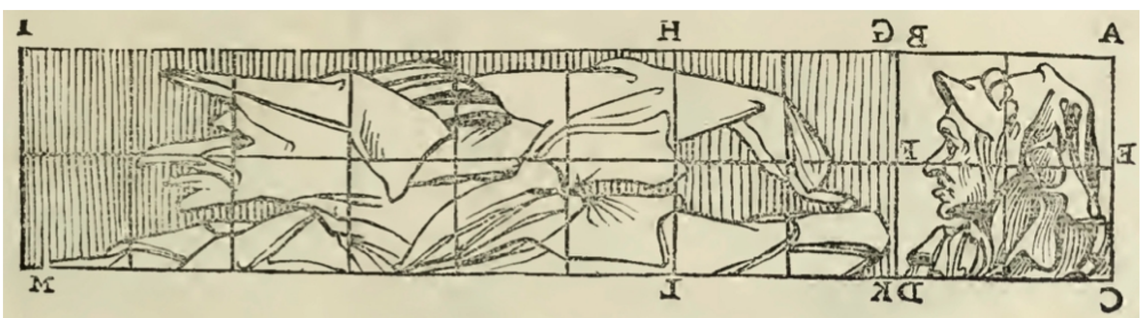

Figure 5: Example of optic anamorphic procedures: anamorphic deformation realized without a specific point of view by J. Barozzi, E. Danti, 1583 (*Le due regole della prospettiva*, pp. 96).

Under the overwhelming influence of the scientific revolution that characterized the seventeenth century, a widespread condition of uncertainty and a new attitude towards a measurable approach to reality lead to a new artistic direction.

In these particular conditions, Anamorphosis presents itself as the favorable means to escape from a confusing reality. Furthermore, thanks to the renewed interest in the scientific and mathematical fields, Anamorphosis exceeds its empirical approach in favor of a deeper technical attitude.

Among the treaties, that have taken part in the definition of the geometrical principles of Anamorphosis, we can mention: *La perspective avec la reason des ombres et miroris* by Salomon de Caus (1612), *Lo inganno degli occhi, prospettiva pratica* by Pietro Accolti (1625), *La Perspective cilindrique et conique* by Sieur De Vaulezard (1630) and the masterpiece on the anamorphic studies: *La Perspective curieuse ou magie artificielle de effets merveilleux* by Jean François Nicéron (1638) [9].

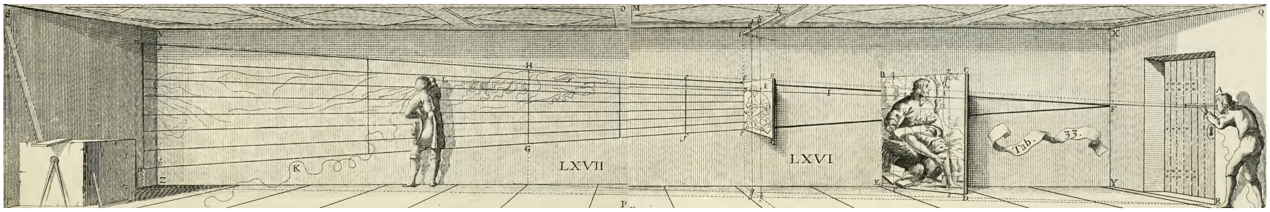


Figure 6: Example of optic anamorphic procedures: anamorphic deformation realized with a distance point and the diagonal rule by J. F. Nicéron, 1646 (*Thaumaturgus opticus*, Tav XXIII).

### 2.1. Geometrical principles of the traditional anamorphic procedures

The procedural methodology for drawing optical anamorphic images can be seen in Figure 6. The original drawing, which is usually enclosed in a grid, is hanged perpendicularly on the wall; its deformation is obtained from the intersection of the visual rays, which are directed from the observer to the preparatory drawing, with the wall, where the Anamorphosis is supposed to appear. By setting the distance point and, from it, the diagonal intersecting the transverse lines of the grid, we obtain the perspective sloping of the medians. The oblique position of the viewer, towards the representational surface, produces a distortion of the squares into trapezoids. Once the grid has been opportunely deformed, the figure is distorted into each sector, resulting in an obscure tangle of lines, which will be revealed only from a single view point.

We refer to catoptric Anamorphosis when a mediating device, know as *anamorphoscope*, is needed to reveal the illusion. The mirrored entity, which in the sixteenth century treatise was always considered tobe a conical or cylindrical shape, has to be placed on the plane, where the deformed image is drawn. This type of Anamorphosis, revolves around the laws of optics and reflection to obtain the distorted image of the preparatory prototype.

Jean François Nicéron dedicates the third book of his treaties, *La Perspective curieuse*, to the description of the geometrical procedures to obtain catoptric Anamorphosis on both conical and cylindrical devices.

The process of their generation involves both the rigid laws of perspective as much as the field of geometrical optics, resulting in the extraordinary changes of the initial image (Figures 8 and 9). The anamorphic picture is obtained by following three basic steps: the first one produces the anamorphic projection of the preliminary image on the solid surface, taking advantage of the geometrical optics procedures. The second one, rather, uses the laws of reflection, which are based on incident and reflection rays, to achieve its catoptric distortion on the representation plane.

In the end the image is transposed from the preparatory prototype into the anamorphic grid, paying attention to its appropriate distortion. The result is a confused and disrupted image which envelopesaround the solid, chosen as a mirror, in such a way that itcan be recomposed in its natural state, onlyif it is observed from a predetermined point of view.

To ascertain the relation between Nicéron's construction and the algorithm that translates it into a digital experiment, a further analysis of the historical anamorphic procedure is needed.

The geometrical scheme described by Jean Francois Nicéron (Figure 7) consists of the base of the cylindrical mirror (EDGF), the visual axis (AB), and the two tangent rays BDV and BEX), which represent the maximum amplitude of the optical pyramid. The points of

[2] © National Gallery, Trafalgar Square, London WC2N 5DN.

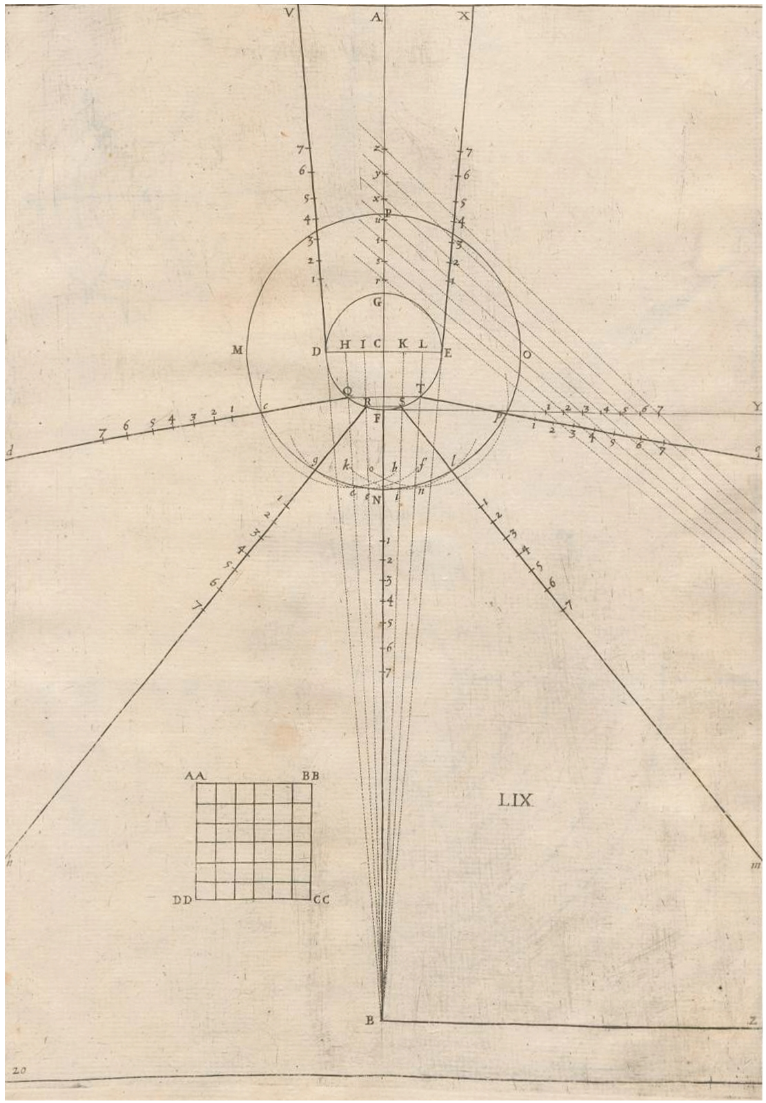

Figure 7: Geometrical procedures of the catoptric Anamorphosis on a mirrored cylinder, J.F. Nicéron, 1638 (*La Perspective curieuse*, Tav XX).

view as well as the side of the cylinder FY are fixed on the Z-axis. DE, the projection of the picture plane, in which the prototype image is virtually contained, coincides with the diameter of the base of the cylinder. The prototype divisions (1, 2, 3, 4, 5, 6, 7) are transferred on the side of the cylinder (FY) at the height where the reflex image will appear. The rays departing from Z, which intersect these points, are directed to the axis (BA) on which they point their projections (r, s, t, u, x, y, z). These projections are plotted on the uprights of the anamorphic grid with arches of a circle having center points Q, R, S, F, S, T, and progressive opening in r, s, t, u, x, y, z . The curves connecting the points with the same number are the anamorphic transversals of the grid.

The uprights (Qd, Rh, Sm, Tq) are obtained by intersection, with the MNO concentric circle, of a series of arches of circles. With center at the points of incidence Q, R, F, S and T and progressive opening at points a, and, n, found by the intersection of MNO with the incident rays, trace four circumferences that, intersecting the major circumference MNO, will establish the points c, g, l, p, from which the deformed uprights pass through the picture plane.

## 3. Anamorphic digitalization

In the first part of the study we have taken advantage of the potential of the digital platform to support the mere visualization and comprehension of the geometrical entities in space. In this section we aim for the automation of a geometrical procedure which has been debated for more than two decades; not only in order to revitalize an historical practice, but especially to gain a stronger spatial and geometrical awareness, which is essential to forge a new language of representation.

The reason behind the choice of considering the catoptric Anamorphosis, as the case study of application of the digital procedures of this paper, resides in its multifaceted nature. As we mentioned in the previous section, it is based on a process that involves both the perspective procedures, applied at the optic case study, and the laws of reflection related to the mirrored surfaces.

The interest in the anamorphic field comes from the deep theoretical and graphical potentials within its geometrical procedures. The use of a three-dimensional modeling platform has allowed not only the visualization of the elements in space, but, specifically, the understanding of the innate relationship between geometrical entities. The dimensional characteristics of the system components follow those set out in Nicéron's treatise. This choice allows experimentation upon the original geometrical procedures, but also a comparison of the historical anamorphic image, with the one obtained in a flexible three-dimensional environment, always based on the teachings of the past.

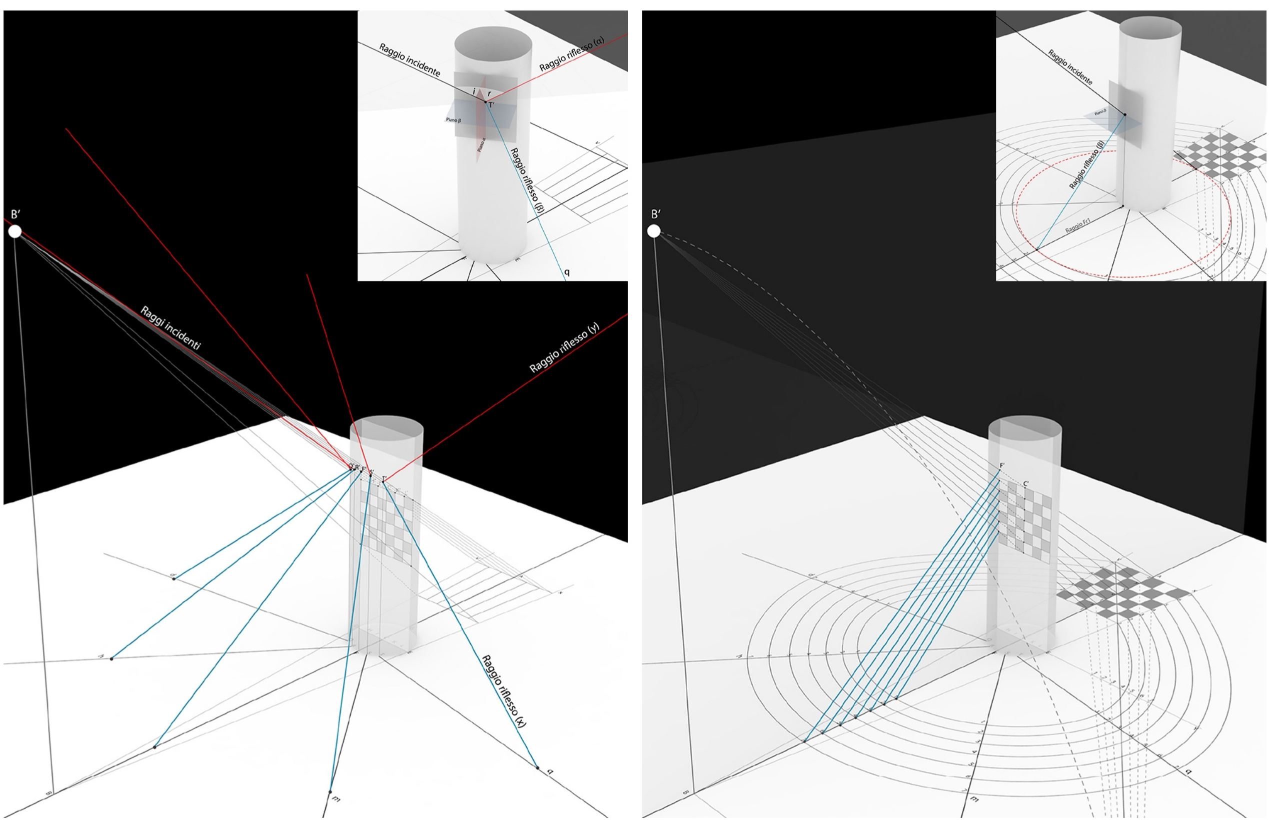


Figure 8: Geometrical procedures of the catoptric Anamorphosis on a mirrored cylinder (drawing by author).

### 3.1. Catoptric Anamorphosis on mirrored surface

In this subsection we apply Nicéron's catoptric techniques to a cylindrical specular surface.

In order to achieve a virtual re-creation of the anamorphic procedures, an algorithm has been developed by using the parametric editor *Grasshopper* integrated with the 3D modeling program *Rhinoceros*, based on the geometrical operations of projection, intersection, and reflection, inspired by the principles of Descriptive Geometry and Catoptrics. The use of such programs allows the generation of a self-referential interactive model, able to strengthen, through the analysis of the innate relation between geometrical entities, the educational knowledge. Figure 9 provides the three-dimensional reproduction of the seventeenth century catoptric system, described before. The elements such as the plane of representation, the point of view, the prototype and the specular cylindrical surface are referenced in the space through the mathematical parameters *surface, point, curve* and *cylinder*.

The preparatory image is inscribed in a squared grid, which is conveniently divided in 36 smaller sectors. The vectored prototype lies on a plane, which is perpendicular to the base of the cylinder and contains the geometrical axis of the solid; furthermore the author determines its height from the representation plane.

For the sake of clarity it has been decided to only use, as a prototype, the grid first and subsequently a figure inserted within it. We proceeded in the division of the *curve* in a number of parts, as desired.

A prototype image, based on a high number of divisions, leads to greater precision in the

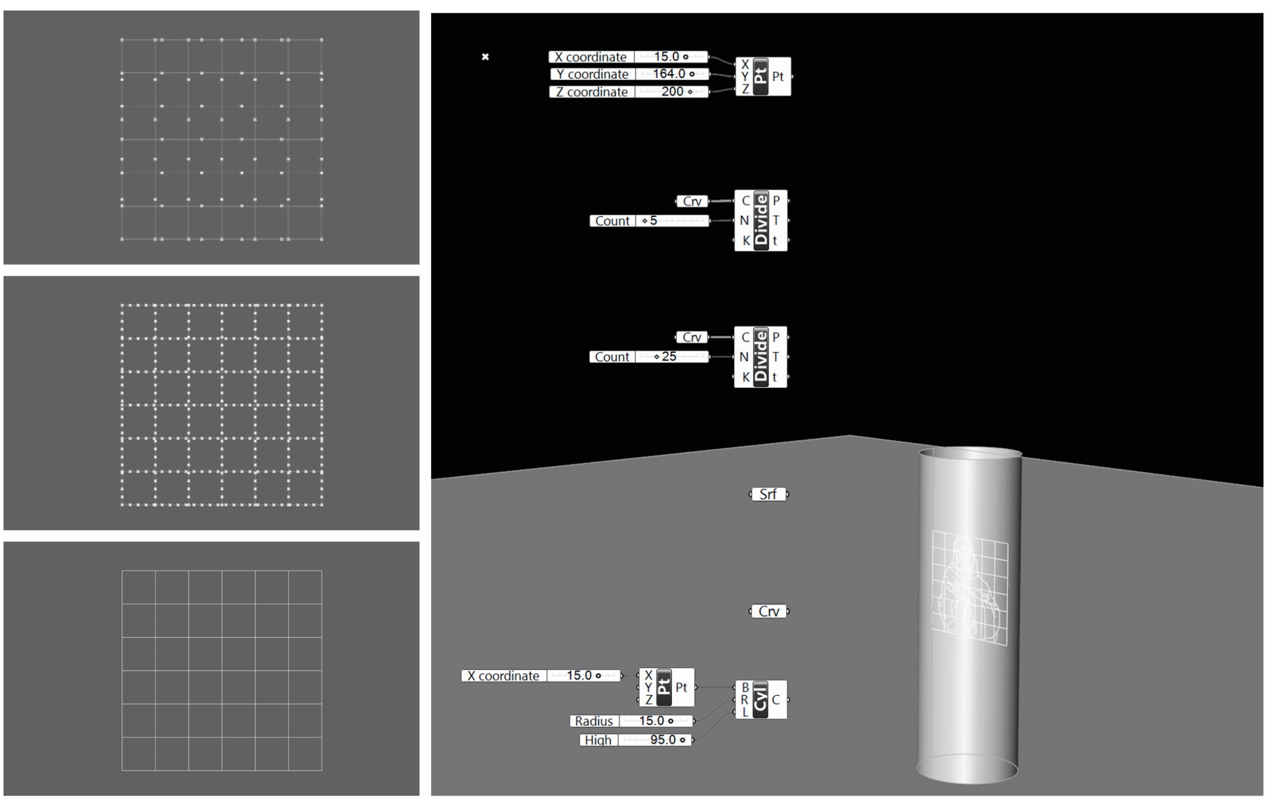


Figure 9: Given a referenced system, consisting of the plane of representation, a point of view, the cylindrical mirrored surface and the prototype image, we proceed to the division of the grid into a variable number of points determined by the numeric slider of the divide command.

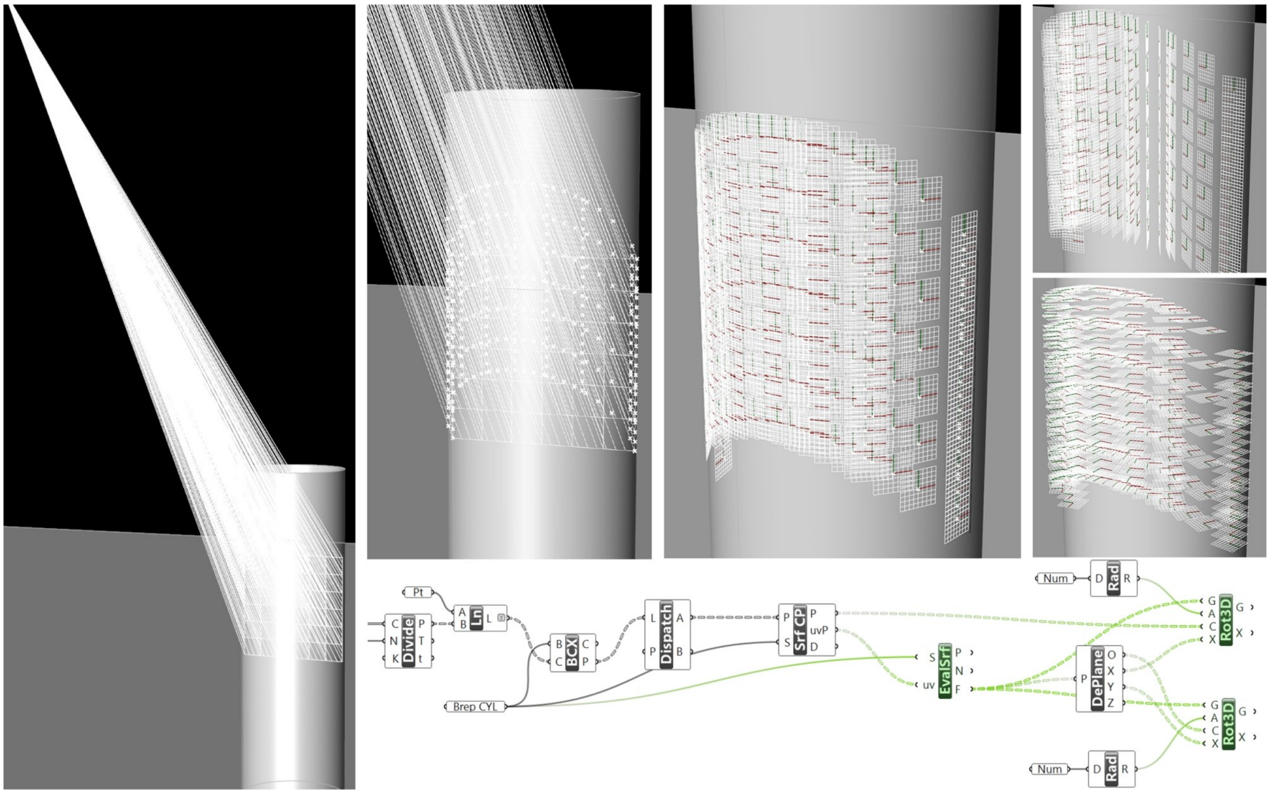


Figure 10: On the Left: Identification of the intersecting points of the visual rays with the surface of the cylinder. On the right: the generation of the system of planes needed to obtain the reflection rays.

generation of the anamorphic curve. This expedient creates a very dense network of anchor points and, consequently, increases the number of visual rays that insist on them.

This operation is particularly influent on the accuracy of the anamorphic image on the plane. As a matter of fact, for every ray that insists on an anchoring point there will correspond a complimentary reflection point, which will intersect the representational surface.

A numeric slider, inputs to the command *divide*, allows the management of this operation. By varying its value, the number of points identified on the curves are increased or decreased. Figure 9 shows the variation of the anchoring points on the grid, while the number entered in the slider is being varied between 5 and 25. The latter was the measure that has been set for the anamorphic process. It has been noticed that for values over 25 the sinuosity of the deformed image would have remained unchanged.

At first, the catoptrical anamorphic process takes advantage of the perspective principle to project the prototype image on the cylindrical surface, as a result of the intersection of the visual rays with the geometrical entity.

In order to obtain the incident rays departing from the point of view and reaching the prototype image enclosed in the mirrored geometrical entity, the *line* component has been used, which requires, as an input, those points defined on the prototype grid.

With the *Brep*|*curve* component we proceed to identify the points of tangency of the bundle of lines with the cylinder surface. This command allows, given a polysurface and a set of curves, the definition of their intersection. It was finally necessary to associate those points at the surface. The result was achieved with the *Surface closest point* component.

This is no more than the normal visual process, in which the optical rays heading towards the prototype intercept what is found on their path (the cylinder surface in our case) (Figure 10). The optical anamorphic image would be obtained on the cylinder surface by joining the previous points together.

According to geometrical optics principles, and the laws of reflection, every incident ray that affects the cylindrical surface subtends, with the orthogonal, an angle of incidence that is equal to the angle of reflection. In order to obtain the reflection rays, a system of planes must be set, which are used as a reference surface to mirror the incidence lines.

The parameter *evaluate surface* and *plane Normal* perform this task: the first one collects data relating to the normal in every incident point; the second one generates its tangent plane.

The perpendicular planes, instead, come from the deconstruction (*Deconstruct plane*) and a 90° rotation (*Rotate 3D*), of the tangent plane, respectively according to the $y$-axis first and, secondly, to the $x$-axis (Figure 10).

In order to obtain the reflected rays, it is necessary to perform a mirroring operation of the bundle of incident rays with regard to the perpendicular plane on the $y$-axis. The lines identified, and the respective incident lines, belong to the same plane and form, with the outgoing normal from the incident point, two angles of equal dimension.

At this point the reflection lines have to undergo the last mirroring process, in order to achieve their intersection with the surface of representation; this time according to the horizontal perpendicular plane. *Surface|line* and *Surface closest point* solve the intersection of the lines and the surface of the representation, identifying the physical intersection points.

The catoptric Anamorphosis on a cylindrical surface is fully completed once the interpolated curves, between the anamorphic points on the surface, are generated through the use of the *Curve on surface* component (Figure 11).

The parametric system developed using the simple grid as a preparatory drawing can be adapted to every possible vectored image.

In order to ensure a greater adherence to Nicéron's treatise [9], Figure 12 shows the specific case in which the historical picture of a human face is reproduced within the reference grid. It is clear that the grid, in the digital system, is no longer an essential parameter to the generation of the warped image on the plane of representation.

The consistency and accuracy of the experimental procedure can be revealed in the modeling software by attributing a reflective material to the cylinder and rendering the image from the determined point of view, by setting a virtual camera, and a target point. As we can see in Figure 12, the mirrored entity reflects the anamorphic drawing, which is deformed all around it, in its normal proportion.

Figure 13 shows a catoptric Anamorphosis on a cone-mirrored surface; it has been obtained by simply changing the reflective entity, the point of view, which is aligned with the geometrical axes of the solid and the vectored prototype, is inscribed in the base of the conical surface.

The flexibility of the algorithm resides in the possibility of interaction with the principle elements of the anamorphic procedure, at every stage of the process. Basing its geometrical system on fundamental entities (points, lines, planes), it can be applied independently to obtain any kind of Anamorphosis configuration. It is this last feature that opens up new horizons in the study of this particular form of representation and leads to a theoretical innovation of a procedure, which, since the seventeenth century, has remained unchanged due to the complexity of its geometrical control.

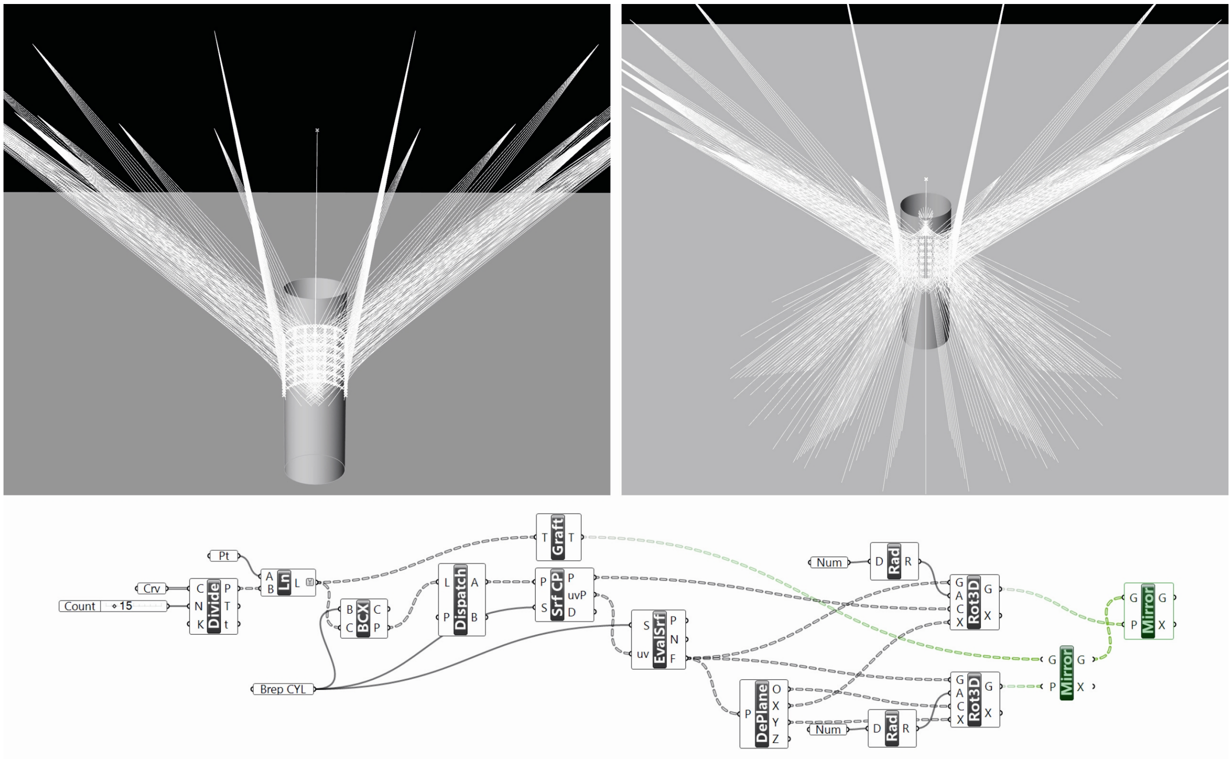


Figure 11: On the left: the system of the reflection rays; on the right: The anamorphic grid on the re-presentation plane is obtained by the union of the intersection points of the reflective rays with the surface, with a series of interpolation lines.

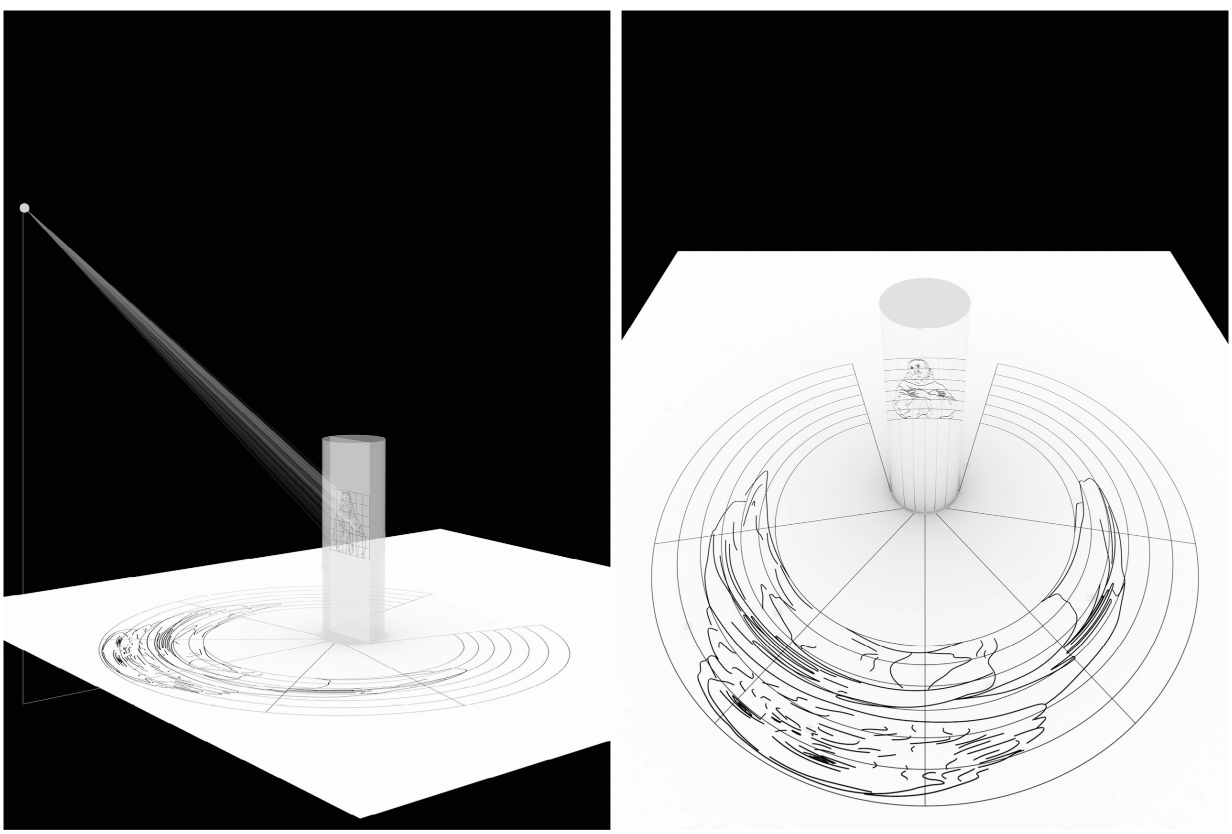

Figure 12: On the left: isometric view of the cylindrical catoptric system; on the right: the Anamorphosis is verified by looking from the specific point of view of the geometrical system.

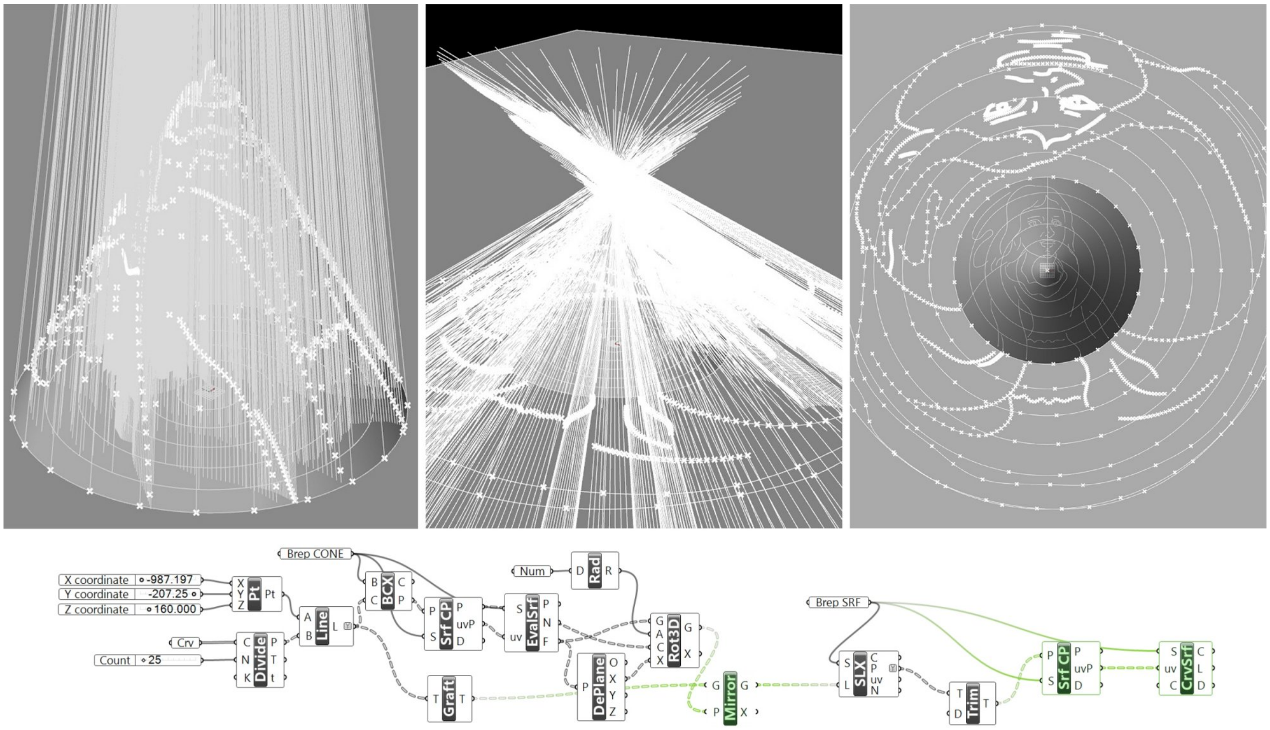


Figure 13: Catoptric Anamorphosis on a conical mirrored surface. The point of view is located on the axes of the cone and the prototype image is inscribed in the base of the solid.

## 4. Conclusions

The studies conducted in the experimental stage of this paper have highlighted the potential of integrating traditional geometrical methods with digital space, from which Anamorphosis is freed from the ancient geometrical limitations and opened up to a new scope of application.

The first set of considerations relates to the possible implications that the experimental phase of this study could have on the definition of a new language of representation. With the dispersion of new computer systems, the introduction of the virtual space and the development of digital imaging technologies, the representative language of architecture has undergone a major expansion in its field.

Crossing the threshold of virtuality, the illustration exceeds its expressive role and becomes a means for a new visual perception of reality. This significant shift stimulates a profound reflection on the real aims of representation and of its expressive language.

This study, together with the experiments carried out on Nicéron's anamorphic procedures, have proved that the integration of the classical techniques of Descriptive Geometry, with the new technologies available today, can bring many benefits within the practice of architecture.

In a virtual reality, in which students, designers and artists are now easily able to reproduce any environment or situation, according to a series of graphical operations, the control of those gestures, movements and measures operated in space is fading away.

One of the benefits of illustrating the anamorphic problems in a three-dimensional digital space is the technical awareness of the geometrical operations. The obtained algorithm represents the synthesis between the technical rigor of the seventeenth century treatises and a flexible digital system, in which each element can be investigated and freely transformed. The system variables (the point of view, the plane of the representation, the prototype image and

Figure 14: Applications of the anamorphic procedure. *"Qui croire?"* by F. Abélanet – The Anamorphist®, Paris, with kind permission by the artist (www.francois-abelanet.com).

the geometrical entity) can be modified during the whole process, in order to meet any need.

The second set of considerations concerns the implications of the anamorphic techniques in modern architecture. Urban space is changing and is directing its attention to new experiences in the field of perception. On the flow of this technological revolution, Anamorphosis opens up new scenarios, directed to a synthesis with architecture and urban space.

Projects like the *ephemeral garden* by François Abélanet – The Anamorphist® (Figure 14) or the anamorphic spatial experiments by Felice Varini[3] and Leandro Erlich[4], show a growing interest in the integration of the extraordinary strength of Anamorphosis in the modern architectural context, towards the definition of a new relationship between user and architecture.

The integration of the expressive potential of Anamorphosis within the design process may activate a dynamic metamorphosis in the architecture field, able to shape new spaces and to give them different expressive connotations.

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[3]note *'Huit Carre's'*, Versailles, http://www.varini.org/doshpdv/b124hd.html

[4]note *'Dalston House'*, https://www.dezeen.com/2013/06/26/dalston-house-by-leandro-erlich/

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