Perspective with Nature: Daniele Barbaro, Jean François Niceron and a Device of Giovanni Battista Vimercati

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Abstract In 1565 Giovanni Battista Vimercati published in Venice a treatise on gnomonics in which there is a device for making copies of sundials. This tool must be exposed under the Sun and contains: two styli; a drawing; and a blank sheet on which to draw the new delineation. The way it works is simple. While one stylus retraces the drawing with its shadow, the other projects an equal shadow that makes the user able to draw a copy. Vimercati did not explain the geometric rules underlying his device and did not indicate relations with other scientific or practical fields. A few years later, Barbaro will explain the link between perspective and gnomonics, just mentioning the tool of Vimercati. In his treatise Barbaro demonstrates also why we should consider the rays of light like physical elements that embody the geometric process of vision. In the following century Jean Fraçois Niceron understood the true potential of Vimercati's tool by projecting the shadow of a stylus on all kind of surfaces. The Minim friar used this gnomonic device to obtain anamorphoses. So, Vimercati's tool epitomizes the physical connection between light and visual rays, acting as a bridge between sundials and vision.

Keywords Mathematics · Geometry · Gnomonics · Perspective

1 Filology and Gnomonics in the Renaissance

After the ancients, gnomonics did not develop until the Renaissance. The new studies were made by astronomers like: Regiomontanus, Sebastian Münster, Petrus Apianus, Francesco Maurolico, Giovanni Battista Vimercati. As happened with other disciplines, the philological passion drove scholars towards a renewal of gnomonics. They studied the treatises of Greek and Roman scientists, who had successfully realized sundials able to describe the motion of the sky. The astronomer Geminus of Rhodes indicated the simplest models of the universe with the term *sphairopoiïa*, referring to the supracelestial sphere [1], while Vitruvius has handed down some devices

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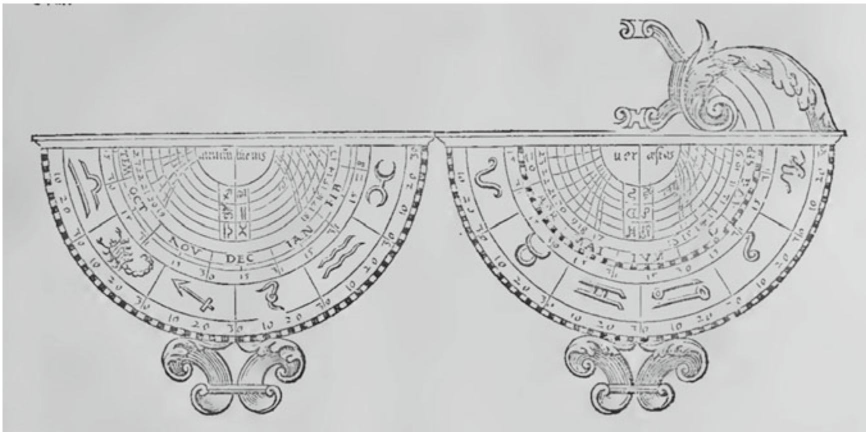

Fig. 1 D. Barbaro, Vitruvius' *Ten Books of Architecture* (1556), semicircular hanging sundial

designed to mark the hours of the day as well as the most important dates of the year. So, we should not be surprised by the philological work carried out by Daniele Barbaro in his comments to Vitruvius's Book IX, because he wished to bring again to life (at least in a printed book) some devices, in his mind lost and forgotten over the centuries (Fig. 1).

One would expect to find the same scientific attempt also in the second edition of the comments to Vitruvius but, in this case, Barbaro eliminated all the reconstructions of the ancient gnomonic devices [2]. This drastic simplification is only apparently in contrast with the author's philological purposes, since: "The sundials discovered by ancients and listed here by Vitruvius can be imagined by those who well understand the circles of the sphere and know the rationale of analemmas because then each can be accommodated to whatever form is desired" [3]. These words indicate that the decision to remove in the second edition images and descriptions of ancient sundials is, however, profoundly humanistic. Barbaro preferred to deal with something more important, namely the explanation of the scientific principles of gnomonics. To do this he mentioned Federico Commandino, who had interpreted and published two fundamental Greek works: *Planisphaerium* [4] and *Liber de Analemmate* [5] by Claudius Ptolemy. While Daniele Barbaro is explaining the gnomonic theory of the ancients, he clarifies that there are common geometric principles underlying different disciplines, such as astronomy, geography and linear perspective. Federico Commandino had made a fleeting reference to this connection in the introductory letter to Ptolemy's *Planisphaerium.* Where he specifies that he drew inspiration from the practices in use at the painters' workshops, to solve problems relating to the representation on a plane of geographical parallels and meridians. But Barbaro goes further, explaining this underlying mathematical link and specifying that it is necessary to know the theory of conic sections of Apollonius, before studying these disciplines.

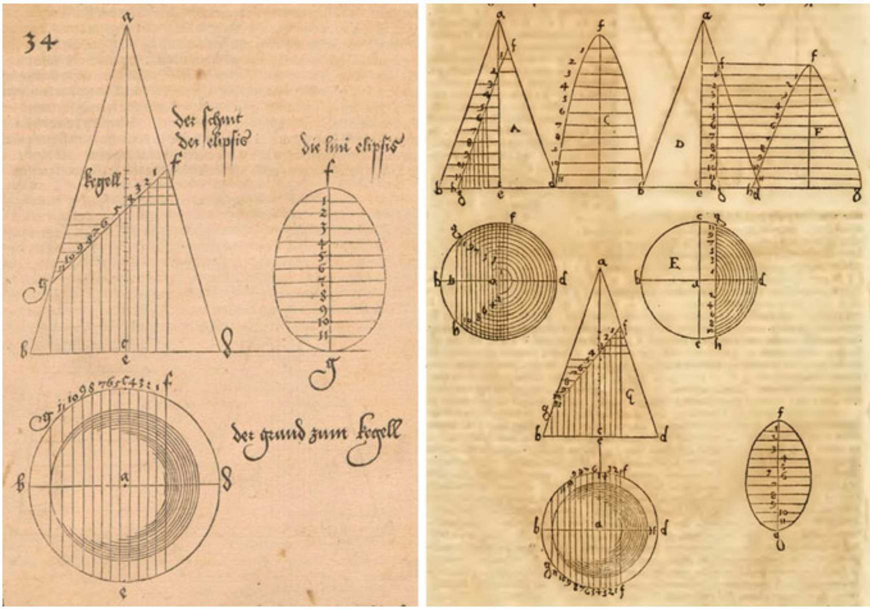

Fig. 2 A. Dürer (left), *Underweysung der Messung* (1525); D. Barbaro (right), *Vitruvius' Ten Books of Architecture* (1567). Conic sections

Always careful to avoid long theoretical disquisitions, he makes use of "the method proposed by Albrecht Dürer, although there are also other ways" [6]. As usual, recognizing perfection in the work of other authors, Barbaro copied the figures published in the *Underweysung der Messung*, where an ellipse, a parabola and a hyperbole, have been represented using three projections of the cone and the construction with 'horizontal sections' (Fig. 2).

Finally, perhaps because aware that the connection between the sections of the cone and the gnomonics may not be easily understood by all readers, Barbaro warns that: "Now, in order that you know the reason why we have explained these figures, I say that the sun, revolving from day to day, sends its rays to the gnomon, the tip of which we imagine as being the apex of a cone; the circle that the sun makes is the base of the cone; and the rays that go from the body of the sun are that line which, turning around, describes the cone. If we think carefully about this effect that the sun makes with its rays in the gnomon, we will see that it makes a conic surface because it is a surface made of two surfaces on opposite sides of the apex of a cone: one is the circle that the sun makes above the tip of the gnomon, the other is one going down from the tip of the gnomon in the opposite direction, which would go on infinitely if it were not opposed by a plane. Since this plane is opposed in different ways [i.e., lies at different angles], and cuts this rays of the lower conic surface, it is necessary to consider the properties of those cuts because they make different lines" [7].

Gnomonics and linear perspective have not only common geometric basis; similarities can also be found in their practical approach. Despite a dimensional difference due to the fact that astronomers work in space, while the painters refer to a plane, the way to sight the celestial bodies by means of moving circles, as suggested by Federico Commandino in the *Liber de Analemmate*, is very similar to that which the artists perform when they transport on the canvas the points of intersection between the visual ray and the pictorial plane. We also find in Barbaro's treatise that the astrolabe, one of the most popular astronomical instruments, requires that its analemma must be built using the rules of perspective. In this case we should proceed in the manner of geographers, as Commandino teaches in his comments to Ptolemy's *Planisphaerium*, that is, by projecting the circles of the celestial sphere on a plane from the South Pole.

2 Conic Section, Gnomonics and Linear Perspective

After these considerations I would like to describe the problem from a geometric point of view, referring to a horizontal sundial. Every day of the year the Sun rises and sets above the horizon, outlining a circular trajectory in the sky (red line). This arc constitutes the base of a double cone, with its apex at the tip of the gnomon. One of these cones is made of light, because the lines that generate its surface are the rays of the Sun, while the other cone is made by shadow rays. This cone, made of shadow, is cut by an oblique plane, if we refer to the axis of this cone, and the section that this cut generates is usually a hyperbole (blue line). However, two days a year, during the equinoxes, it happens that the section of the shadow cone is a straight line, because the circular trajectory of the Sun and the tip of the gnomon are contained in the same plane, named equinoctial (Fig. 3).

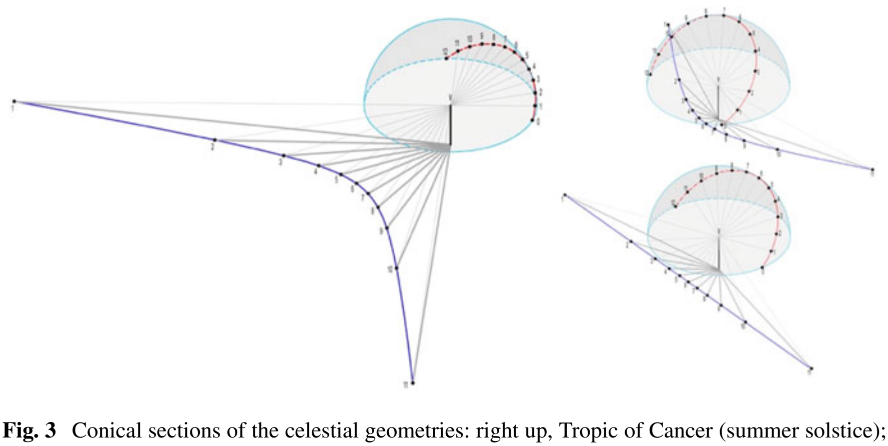

Fig. 3 Conical sections of the celestial geometries: right up, Tropic of Cancer (summer solstice); right down, Aries and Libra (equinoxes); left, Tropic of Capricorn (winter solstice)

The geometric link between conic sections, gnomonic and perspective, is made even more explicit in the description of Daniele Barbaro's *horario universale*, a device that works as a sundial and can be used to mark the time and to make sundials [8]. The illustration, provided by the Venetian nobleman, shows a sequence of disembodied eyes, emanating straight lines, that are set along the Tropic of Cancer. So, the visual rays replace both the luminous rays of the Sun and those of the shadows. Barbaro's instrument is an object similar to an armillary sphere because it is a simplified representation of the celestial sphere plus: the poles; the polar circles; the two coluri; the horizon; the tropic of Cancer; and the tropic of Capricorn. Thus composed, according to the definition given by Geminus, it is still a simple *sphairopoiïa*, that is an interpretation of the cosmos, but Barbaro transforms this tool into a sundial by adding 24 portions of meridians. These arches divide the two tropics into equal parts and fix the astronomical hours.

The perfect coincidence between light-shadow rays and visual ones reaches in these illustrations an adamant clarity. The only problem is that it raises an implicit issue linked to the position that the terms of a Renaissance perspective normally occupy. The painters had the habit to consider the pictorial plane interposed between the eye of the observer and the object to be drawn. But, relying on the rules of gnomonics, Daniele Barbaro shows that it is possible to revolutionize the spatial arrangement of these elements. In the art of tracing sundials, the eye is replaced by the tip of the gnomon while the pictorial plane is beyond the object to be represented. Indeed, the spatial sequence eye-pictorial plane-object is shuffled into another order: eye-object-pictorial plane. The effects that Barbaro's universal sundials will have in the following years, after the publication of *La pratica della perspettiva*, should not be sought in the field of gnomonics since, although innovative, the instrument does not break the traditional patterns of this discipline. Instead, it is appropriate to turn our attention to the changes that occur in the development of perspective theory.

About 75 years after Barbaro's universal sundial appeared, the Minim friar Jean François Niceron published in Paris a Latin work, titled *Thaumaturgus opticus* [9], a scholarly reinterpretation of a previous book in French, *La perpsective curieuse* [10]. In the Latin text some of the principal innovations introduced by Daniele Barbaro found full maturity. Niceron's Figure XXXVIII illustrates a mixing of the elements of a perspective, which are arranged in the order described by Barbaro [11] (Fig. 4).

The object of the representation is set between the pictorial plane and the observer. It is a diaphanous square that allows visual rays to cross its contours and project them

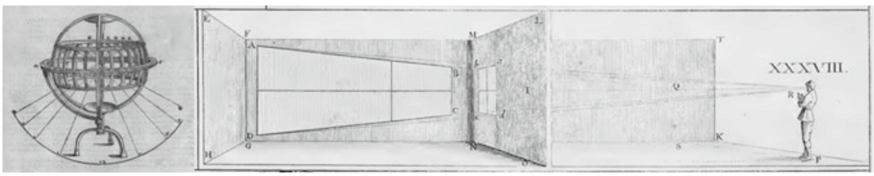

Fig. 4 (left) D. Barbaro, *La pratica della perspettiva* (1568). Horario universale. (right) J. F. Niceron, *Thaumaturgus opticus* (1646). Optical link between square and trapezoid

onto a plane that is very inclined referring to the axis of the visual pyramid. The perspective image that this projection produces is an anamorphosis, an elongated isosceles trapezoid, geometrically different from a square, but optically identical to it, if perceived by the *punctum optimum*.

Inspired by the practice of astronomers, who were able to draw sundials on any kind of surface, the object-picture inversion will free the seventeenth-century artists from outlining perspectives exclusively on a plane, since: "There is no doubt that, if you have well understood the way of forming the sundials in the plane of the horizon, you will be able to draw the sundials in the other straight, hollow, bent or whatever planes" [12]. This is the reason why the famous anamorphoses of Niceron on cones and pyramids, can be traced back to the projected shadows of a gnomon. These strange drawings amaze the observer who, after having positioned his eye in the privileged point of view, is able to grasp their true sense.

3 Drawing with Shade and Shadows

If we consider the method that Daniele Barbaro suggests for outlining an anamorphosis we have to conclude that he had not yet fully understood the difference between cylindrical and conical projections. Indeed, he invites the reader to project a drawing using the light of the Sun instead of a candle. But, Giovanni Battista Vimercati's skiagraphic machine, described in Part Nine of Barbaro's *La pratica della perspectiva*, proves that at least Renaissance astronomers knew well the difference between the two projections. This device, which will be illustrated for the first time by Niceron in his *Thaumaturgus opticus* [13], is an invention of the Milanese monk, described in the *Dialogo de gli horologi solari*, a book published in Ferrara in 1565 [14] (Fig. 5).

Barbaro discovered Vimercati's device probably during his search for perspective tools and trying to complete his knowledge of sundials, a topic that interested him. Describing this skiagraphic machine, he explains that: "With the help of the Sun one drawing of a specific size can be transported to another with that proportion, which a man desires, and he can copy a sundial, a fortress, a human figure, and any

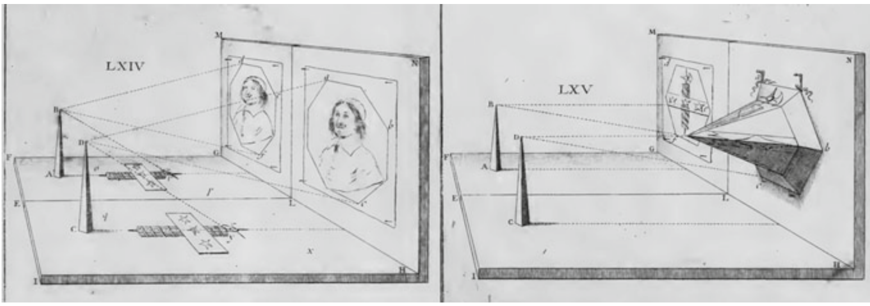

Fig. 5 J. F. Niceron, *Thaumaturgus opticus* (1646). Vimercati's Skiagrafic tool

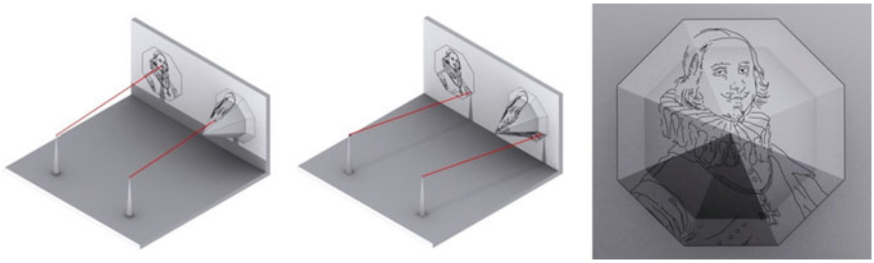

Fig. 6 Skiagrafic tool working and view of the anamorphosis from the tip of the gnomon

other type of thing, as the Milanese Reverend D. Gianbattista Vimercati shows in his book of sundials" [15]. This tool consists of two orthogonal planes; the horizontal one contains two gnomons, that rise on it, while the vertical plane has a drawing and a white paper on which to copy. In practice, starting from a given prototype, a copy of a drawing can be generated, using the projection of the shadow made by a stylus. This skiagraphic machine must be exposed under the parallel rays of the sun rotating it continuously. Following these guidelines, while the shadow generated by the first stylus follows the contours of the prototype-image, the shadow produced by the other gnomon copies this drawing. The draftsman can mark and join the points of the projection on the white paper. From a geometric point of view, Vimercati's instrument transforms parallel rays (cylindrical projection) into rays converging at the vertices of the two gnomons (conical or central projection) (Fig. 6).

In order for the device to work, the straight lines, that carry the shadow, have always to keep the same direction; this occurs only when the light source produces parallel rays, as in the case of the Sun. So, to produce a central projection, emulating the eye vision, it is necessary to rotate the entire system making sure that the shadow follows the drawing you want to copy.

Maybe the time was not yet ripe for Daniele Barbaro to realize that Vimercati's skiagraphic machine was useful not only in the production of equal copies, but also in the production of anamorphoses. However, a doubt arises in favor of his awareness, reading his words: "one can do the same things without the sun, and without a candle, and without the hole-punched paper, and first with the rules set out in the second part about the description of planes, and plans. then with the tools, which I will discuss in the last part" [16]. Talking about anamorphoses, does Barbaro refer to a possible reinterpretation of the Dürer's perspective machine, to the Vimercati's skiagraphic instrument or to the *camera obscura*? Unfortunately, this passage is too vague to formulate a precise hypothesis and in Part Ninth of his treatise Barbaro does not indicate how to use perspective machines to generate anamorphoses.

Many years later, Niceron will pick up all the opportunities offered by the first two prospective devices mentioned. As we said, the Minim friar will describe the function of Vimercati's skiagraphic machine in *Thaumaturgus oprticus*, extending its function for delineating anamorphoses. This important outcome was achieved by applying the projection of the second gnomon on any type of surface "whether they are continuous, discontinuous, sunken, convex, equally extended, protruding, rough, cut, curved, hollowed out and in others of any kind" [17]. All this is possible because the deformed drawing appears identical to the starting one, if the observer places his eye in the vertex of the second stylus, regardless of the geometry of the surface on which the drawing has been projected. Vimercati's illustration of the skiagraphic device clearly shows that Niceron knew that the parallel solar rays after having intercepted the tip of the gnomon change their path creating a conical projection.

While thinking about the way in which nature emulates the mechanism of vision, the Minim friar was not alone, he could count on the help of eminent scientists, gathered in Paris around the philosopher Marin Mersenne. Among them we remember the brother Emmanuel Maignan, physicist and gnomonist, author in Rome of two sundials that use the reflections of the Sun's rays to measure time. Niceron and Maignan experimented together the rules of conical projection in artistic practice.

Along the corridors on the first floor of the convent of Trinità dei Monti in Rome we can admire two extraordinary anamorphic paintings, about 15 meters long each: *Saint Francis of Paola* in *grisaille* [18], work of Maignan; and *Saint John the Evangelist writing the Apocalypse*, painted with tempera colors by Niceron and discovered only in very recent times [19]. Only if the observer, crossing the corridors, conquers the privileged position the anamorphoses the two Saints become intelligible. In any other place, the visitor perceives only a trail of lines, similar to the roughness of a landscape, within which Maignan and Niceron have disseminated respectively: single episodes of the life of Francis of Paola; and the apocalyptic visions received by the Evangelist (Fig. 7).

The way to obtain these anamorphical delineations is well illustrated in Niceron's *Thaumaturgus opticus*. But this method could be very long and boring, because you have to project on the wall each single point through wires (Fig. 8).

If Niceron had wanted to avoid this problem he could have used a device for the anamorphic delineation of his *Saint John The Evangelist*, such as Vimercati's tool. First of all, we should focus on the light source, indeed, this wall painting is an art work created inside a building. Maybe this source was a candle, whose light radiations had been artfully directed to create a set of parallel rays. The control of a light source, transforming it from a central to parallel projection, could have been easily achieved by means of a parabolic mirror with the candle placed in its focus. The

Fig. 7 J. F. Niceron, *Saint John the Evangelist* (left) and two details: the pen/falling water (center) and the book/plowed field (right)

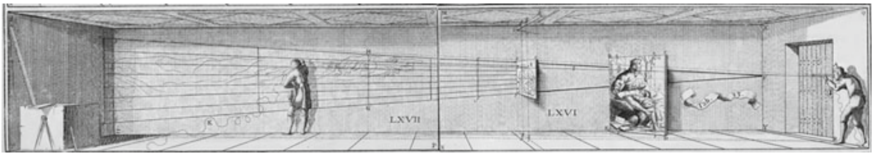

Fig. 8 Niceron, *Thaumaturgus opticus* (1646). Way to trace an anamorphosis

'magical' applications of the mirrors had already been described in the *cogitationes privatae* of Descartes and illustrated by Athanasius Kircher [20]. So, it is plausible to assume that Niceron was perfectly able to transform a point source into a parallel light thanks to a parabolic mirror. To recreate the effects of Vimercati's device, he could have set two obelisks, one in front of the perspective drawing of *Saint John*, and the other in the privileged point of view. In this way, moving and rotating the mirror, the shadow generated by the tip of the first stylus retraces the contours of the drawing, while the shadow produced by the second stylus reaches the wall, where a collaborator can trace the anamorphosis. Such a skiagraphic device would have quicken the tedious identification of each single point, solving also the problem of precision linked to the use of long ropes (Fig. 9).

4 Conclusion

A new interest in Ancients' science led Renaissance scholars to wonder about the common principles that lie under different disciplines. Daniele Barbaro is among the first scholars to point out that conical sections match geographical representation, sundials and linear perspective. From a practical point of view The Venetian scholar makes this connection explicit by listing the instrument of the gnomonist Giovanni Battista Vimercati among the machines useful for copying drawings.

Almost a century later, Jean François Niceron collects the legacy of Barbaro, he illustrates the instrument of Vimercati in his *Thaumaturgus opticus* and perhaps uses it for the realization of the anamorphosis, titled *Saint John the Evangelist writing the Apocalypse*. This means not only that in the seventeenth century scholars know the difference between conical and parallel projection but that they are also able to bend natural phenomena forcing the Sun, or a candle, to draw in their place.

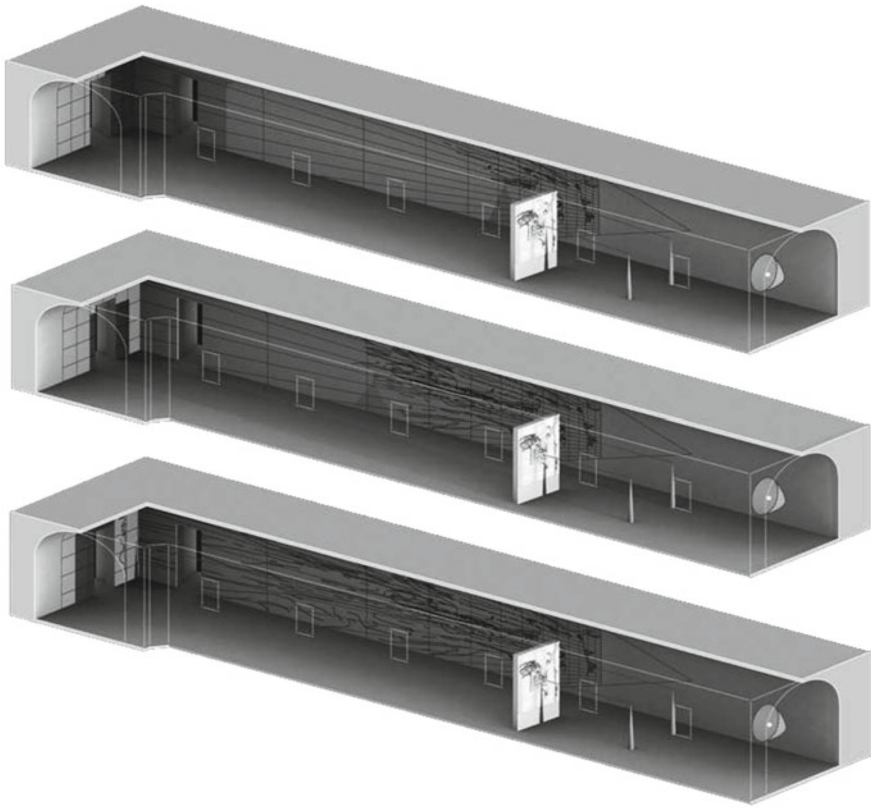

Fig. 9 Hypothesis of application of Vimercati's skiagraphic tool for creating Niceron's anamorphosis of *Saint John the Evangelist* in the corridor of Trinità dei Monti in Rome

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