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OPTICAL RAYS SHINE AS RAYS OF LIGHT: THE CONCEPT OF PROJECTION BETWEEN OPTICS AND GNOMONICS[1]

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Abstract: This paper investigates the relation between anamorphosis and gnomonics in the baroque period. This comparison gives the possibility to analyse the possible use of light to calculate and create anamorphic projections. The relation between rays of vision and rays of light is also connected to the construction of sundials highlighting a similar physical behaviour of these two instruments in projection praxis. The final hypothesis considers the projection in geometry as a concept influenced by the use and study of light propagation.

Keywords: anamorphosis, gnomonics, Maignan, optics, Niceron.

1 Introduction

Since ancient times research about optic and gnomonic has been strictly related to the practice of architecture. According to classical studies one of the most important text is the well-known *De Architettura* written around 15 b.C. by Vitruvio, in particular a whole part of this work is dedicated to the construction of solar clocks [1]. In classical period optic was considered very important not only for the theatre practice (referring to scenic design), but also for the practice of planning that depends on the way space is perceived through senses. On the other side the importance given to gnomonic [2] refers to more general studies about astronomy, in this case the connection with architecture have practical (related to human life) and symbolical meanings such as the will to build monuments along with the harmony of universe.

Both topics had a reawakening in renaissance and baroque period, thanks to the publication and translation of ancient treatises. In XVI and XVII centuries we notice the birth of a new trend: a wide spread of scientific games in courts and palaces shortly took the shape of wonderful private collections (wunderkammer). The sense of wonder for such a kind of instruments and objects could be explained by a certain desire of

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entertainment combined with the research of new scientific experiments in different matters, such as: acoustics, magnetic, existence of void (even for the realization of automaton), astronomy and optic. The state of mind typical of wonder is closely related to the desire of knowledge, this kind of emotion arouses in the man a natural tendency for knowing. However it should be noted that the greek term ‘Thaûma’ – on which words such as thaumázein and thaumastón are built – doesn’t mean only “wonderful thing”, but also “awful thing”.

In this text I intend focusing on light and gaze in their “wonderful” meaning, these two aspects will be analysed with a special attention to their relationship with geometry starting from two important treatises written by two monks in baroque period.

2 Optics and gnomonics

This essay opens with a scientific game (Figure 1), described by the minim friar, Jean François Niceron, in his treatise La Perspective Curieuse ou Magie Artificielle… [3] published for the first time in Paris in 1638. The game, based on the refraction law, is composed by a drawing where some Turkish sultan portraits are represented in front of a monocular, provided with a polyhedral lens positioned in front of the canvas. If the image is observed through the lens a new portrait appears, the one of Luis XIII, result of the addition of some particular parts of each sultan image. The political meaning of this device refers to the fight led by the King of France against the Ottoman Empire to defend Christianity.

During the fall semester 2014 on the occasion of the “Blick Raum Bild” seminary in Kaiserslautern University, we realized the prototype of the lens [4] (Figure 2) described by Niceron: the location of facets on the canvas, refracted by the lens, has been calculated considering the refractive index of the material used (Plexiglas).

This refractive optical game is linked to the theories of visual perception formulated by René Descartes earlier in his Dioptrique [5] and then in his treatise entitled “L’Homme”. According to the philosopher, light rays converge on the back of the eye by drawing point by point the external image reversed, after being dioptrically diverted by the aqueous humour as a glass lens would do (Figure 3). So eyes act mechanically like a darkroom, but Descartes realises that in perceptual process the retinal image needs to be interpreted by brain. In fact he claims that: “it’s the soul seeing, not the eye” and even, according to him, soul is located in a particular area of the brain called “pineal gland”.

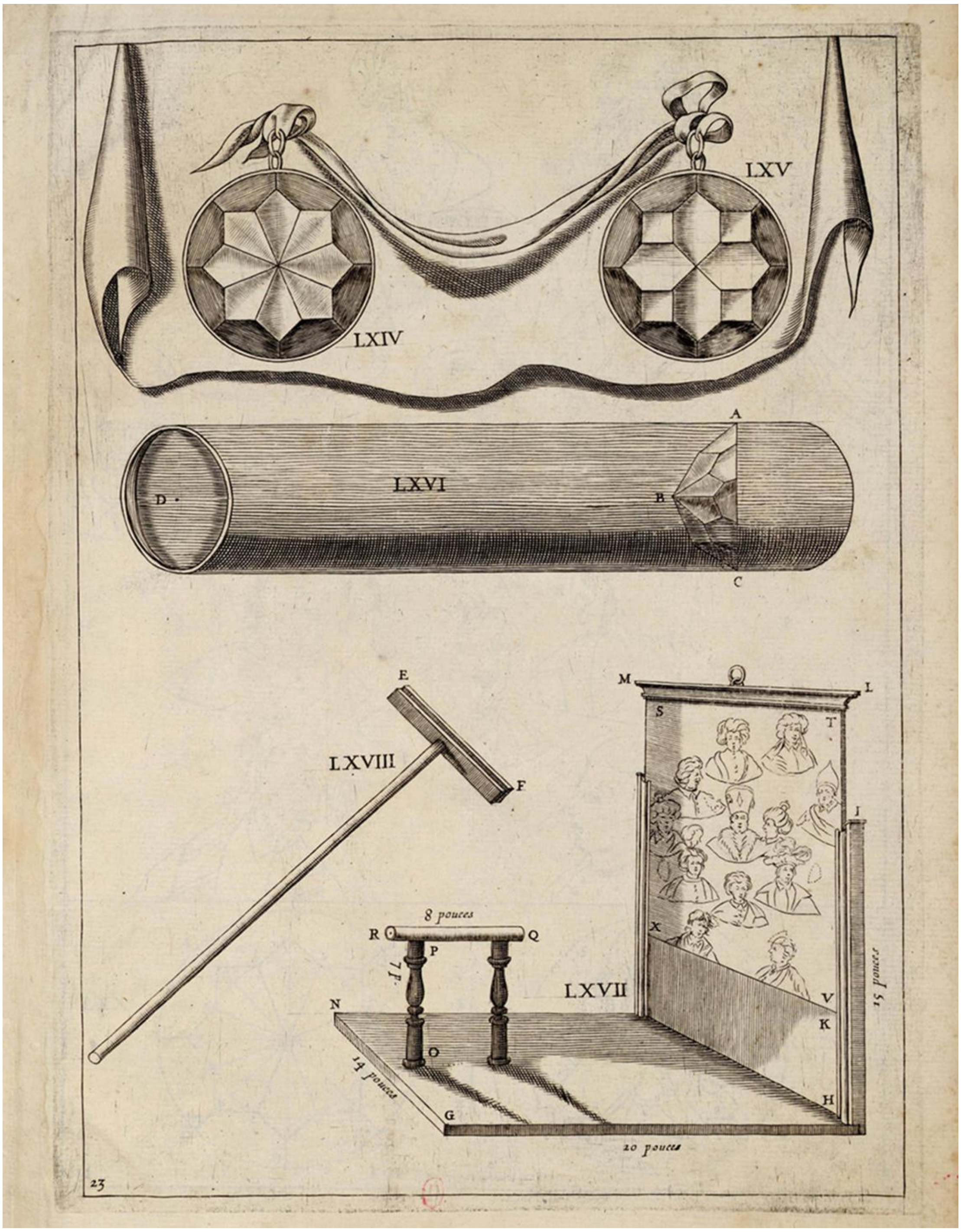

Figure 1 – J. F. Niceron '*La Perspective Curieuse ou Magie Artificielle…*', table 23r

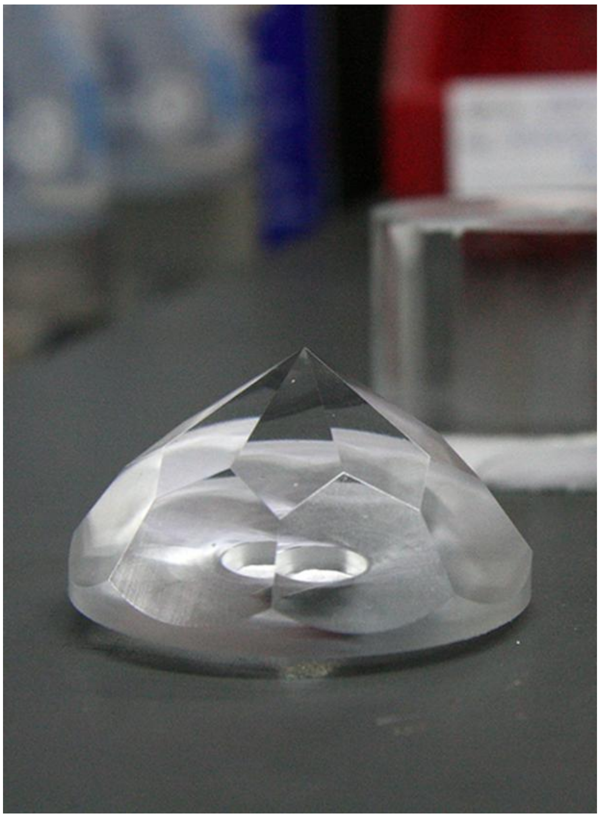

Figure 2 – The milled lens in Plexiglas realized in the TU Kaiserslautern

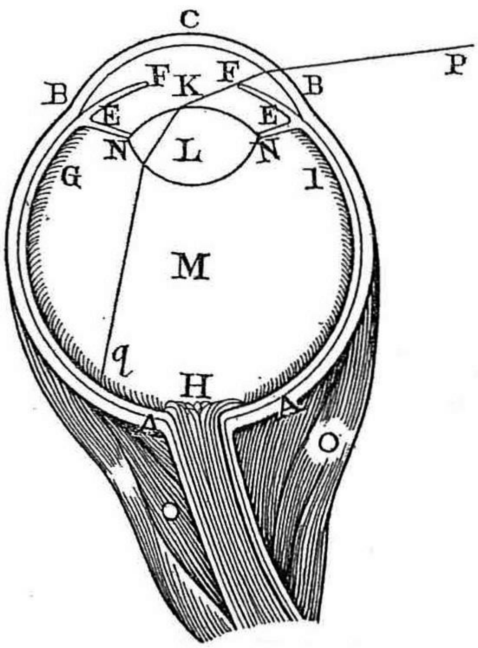

Figure 3 – R. Descartes, *L'homme*, representation of a refracted ray of vision

During the baroque period, when Niceron's treatise appeared, the specific IOR (refractive index) of all kinds of transparent material was unknown [6]. The friar suggests to mark some reference points on the canvas, by looking through the monocle equipped with lens (in particular, Figure 4 shows this method). Some years later, another monk belonging to the order of Jesuits, Mario Bettini, describes how to build the same peepshow in his 'Apiaria Universae Philosophiae Mathematicae' (Bologna 1642) using a different method: a source of light, placed in the same position of the observer's eye, can be used to light up the parts on the plane of the canvas that will be refracted through the lens (Figure 5). Thanks to our prototype we experimented Bettini method, finding that a source of LED light can be used not only to determine the sections of canvas refracted, but also the shape of these parts (Figure 6).

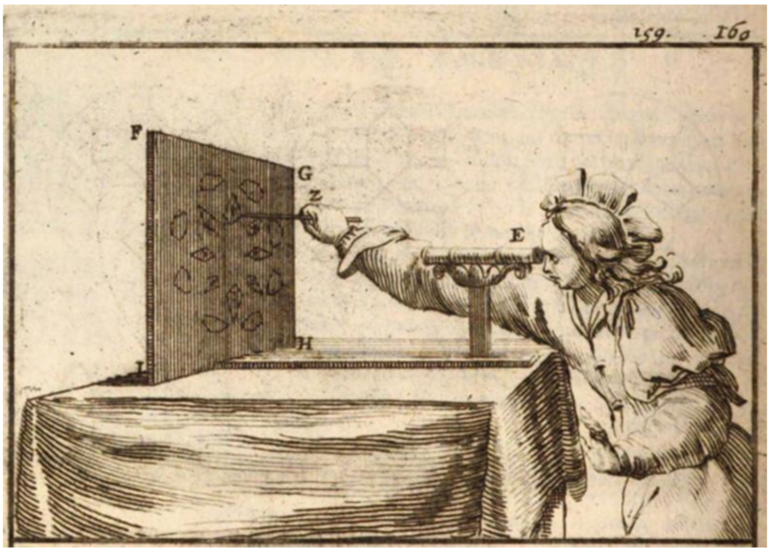

Figure 4 – J. Du Breuil, *La Perspective Pratique*, Parigi 1679. Third part, p. 159

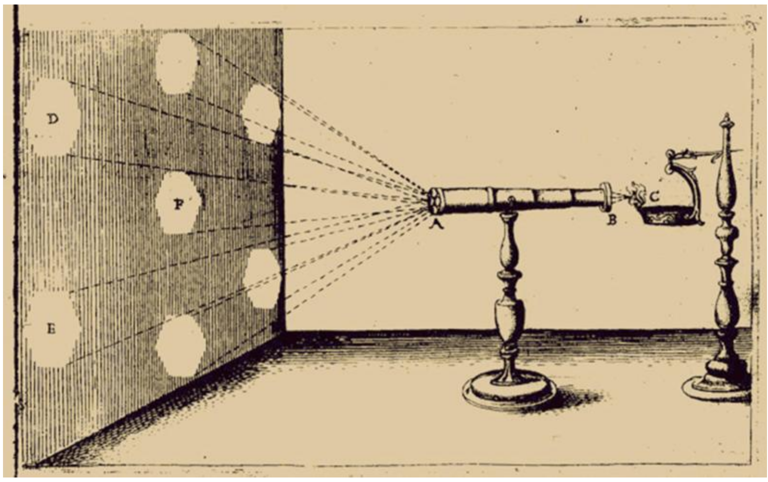

Figure 5 – M. Bettini, *Apiaria Universae Philosophiae Mathematicae*, Bologna 1642. Book V, chapter 3, p. 33

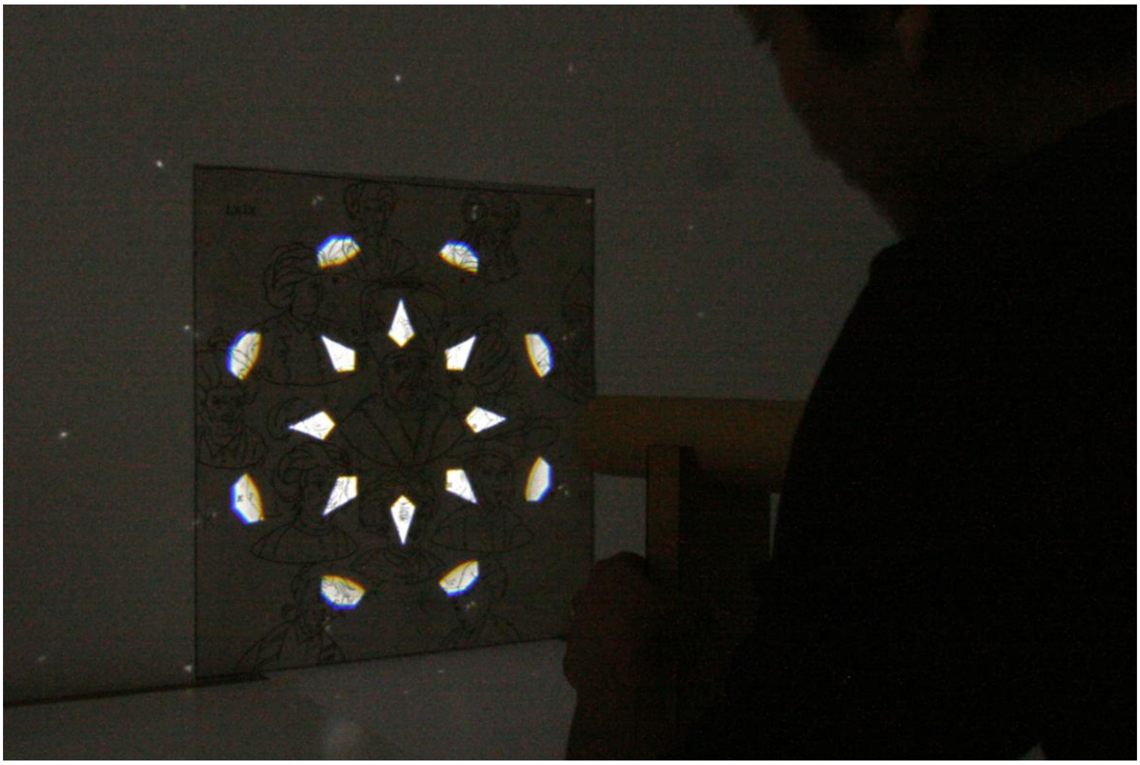

Figure 6 – The use of light for the empirical location of refracted areas on canvas

During the seminary we analyzed and realized all types of anamorphosis [7] depicted by Niceron in his La Perspective Curieuse: direct, catoptric and dioptric (above mentioned) [8]. In the frontispiece it was given a preview of those subjects treated in his work (Figure 7): a group of Erotes is depicted while experiencing the effects of the laws of reflection, refraction and more generally of central projections applied to observation of properly distorted images (optics).

In all cases we demonstrated the correspondence, from a geometrical point of view, between the rays of vision and the rays of light: for example, we realized the direct anamorphosis by projecting an image (or his shadow) on an architectonical surface (floor, wall, ceiling, etc.), using a projector placed in a fixed point that finally represents the observer’s right point of view (Figures 8-9). In other words we can assume that the vertex of the cone of light, emitted by the overhead lamp, corresponds to that of the cone of view: the observer’s eye.

A direct anamorphosis can be obtained in digital environment: at first it is necessary to set a camera, then it needs to locate a virtual and planar imaging outside the architectonical space, this picture will be the base of a cone (directrix) that has the point of view of camera as vertex. A deformed image will come out as result of the intersection between the generatrix of the cone and the surfaces of the building and it will be recognizable only from the point of view set by the camera (Figure 10).

Figure 7 – J. F. Niceron, *La Perspective curieuse….*(Parigi 1638), frontespice

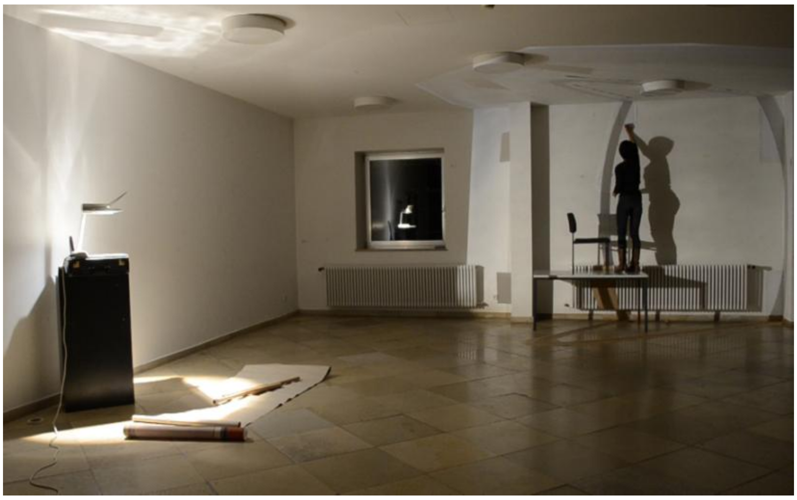

Figure 8 – Realization of the ellipse in anamorphosis with an overhead lamp. Image by Sarah Kannan (student of TU Kaiserslautern)

Figure 9 – The ellipse seen from the overhead projector location

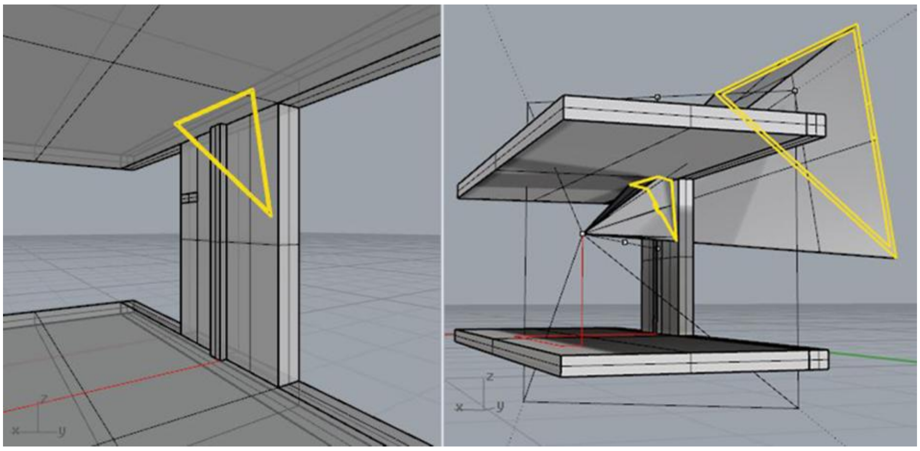

Figure 10 – Building of an anamorphic image with digital tools. Screenshot by Sarah Kannan (student of TU Kaiserslautern)

Niceron spent part of his life (among 1639 and 1642 for two different periods) in the cloister of S.S. Trinità dei Monti in Rome. In the first floor of the building he realized a painting in anamorphosis, representing St. Jones the Evangelist while he is writing the Apocalypse. In this peaceful place he met Emmanuel Maignan, another scientist monk engaged in researches about gnomonic. We know that these men were connected by the common interest for physic experiments and probably they influenced each other. In 1642 Maignan published his first treatise, Perspectiva Horaria [9], where he illustrated how to create different kinds of solar clock in big scale.

The frontispiece of this text bears some similarity to that one of Perspective Curieuse by Niceron. Four female figures can be observed (Figure 11) – the same number of the books composing Perspectiva Horaria – together around a table, located in the central part of the composition. As the Minim explains few lines after in his incipit, “Perspectiva mater suo cum Vitellione” (mother perspective with its son Vitellione), is about teaching its daughters, Optics, Catoptrics and Dioptrics, the rules of gnomonics. It’s obvious the reference to the Perspectiva Libri X written by silesian monk Witelo (1120/30-1314), romanization of his real name Erazm Ciolek, published in 1536 previously in Nuremberg and then in Basel.

On the frontispiece the “sweat daughters” appear in their attemp to experience prospectively those rules they govern: the first one, Optics, focuses on the lines of a sundial traced on the flat surface of the table, she has a style with armillary sphere on her hands casting the shadow that touch the lines; the second one is symbol of the laws of reflection and she conducts operations of a catoptric nature, thanks to a mirror she holds in her hands; the third one has a little bowl adorned with precious stripes containing a liquid inside and she is dedicated to measurement for time, according to the laws of refraction.

The sundials can be classified as ‘direct’ if they use the shadows projected by a beam, as ‘catoptric’ if a mirror is employed to reflect the beam of light on the ceiling of a room and finally as ‘dioptric’ when they are drawn on the bottom of a fountain or on a bowl filled with water. In 1637 Maignan realized a reflective sun clock in the cloister of Rome (Figure 12) and another one in Palazzo Spada in 1644. Inspired by his brother Niceron he painted in anamorphosis, the portrait of St. Francis of Paola, the founder of the minim order, developing the image on the wall and on the barrel vault. The methods for realizing such a big deformed portrait are explained by Maignan in his Perpective Horaria, even if optic is not the main topic of his book, anyway in Propositio LXXVII we can read:

Figure 11 – E. Maignan, *Perspective Horaria*…(Rome 1648), frontespice

"I detached a little from catoptric not because of the similarity of the subject [he is referring to optic, anamorphosis] (that actually doesn't exist) but because of a similarity of the operating principles that we can find in works, however different from each other" [10].

On the author's opinion, the operating principles of optics (perspective and anamorphosis) and gnomonics (for catoptric that's the same) are similar and connected to the idea of projection. So Maignan, in order to create the image of helmit Saint Francis in anamorphosis, pulled those wires representing the clear concretisation of visual rays and moreover producing a luminous cone, whose vertex, where the eye of the observer is located, corresponds at this stage also to an ideal point source of light.

"Any sundial represents a specific projection [projectio] of a sphere and its circles towards some flat surface or any other sort of it."

So, according to Minim monk, optical rays shine as rays of light and they present a similar physical behaviour (Figure 13)

Considering the sundial lines as a geometrical problem, these can be calculated as result of the intersection between cones and planes of light on one side, and planar or curved architectonical surfaces, on the other. More specifically the three curves of hyperbola (cone sections) touched by the shadows of the beam during the equinoxes and solstices, can be drawn by intersecting the cones of light in these precise days with the plan of the quadrant. In this case the vertex of the cone (normally oblique) will be the tip of the gnomon and the diretrix will be the circle described by the sun during his daily apparent movement (Figure 14). The lines of hours represent the intersection between the quadrant and the sheaf of planes whose axis is the style, oriented to the Pole Star [11].

The analogies between the behavior of rays of vision and rays of light give the opportunity to study the sciences of optics and gnomonics by using cone sections. The laws of reflection and refraction were checked by Niceron and Maignan, in different scientific fields with a common aim: understanding the mechanism of perception. The rays of light, compared to the visual ones, take advantage of having a 'material' nature, ready to be observed, so they represent a good support for studying visual phenomena. The idea of visual rays was a concept used in ancient times in trying to explain how you perceive reality through the sight.

We know that in descriptive geometry the idea of projection can be related to the concept of section, but in the evolution of the discipline this affinity became just a theoretical concept and not a practical habit like in the renaissance period.

Figure 12 – The sundial in the cloister of Trinità dei Monti in Rome realized by Emmanuel Maignan in 1637. Picture by A. Bortot

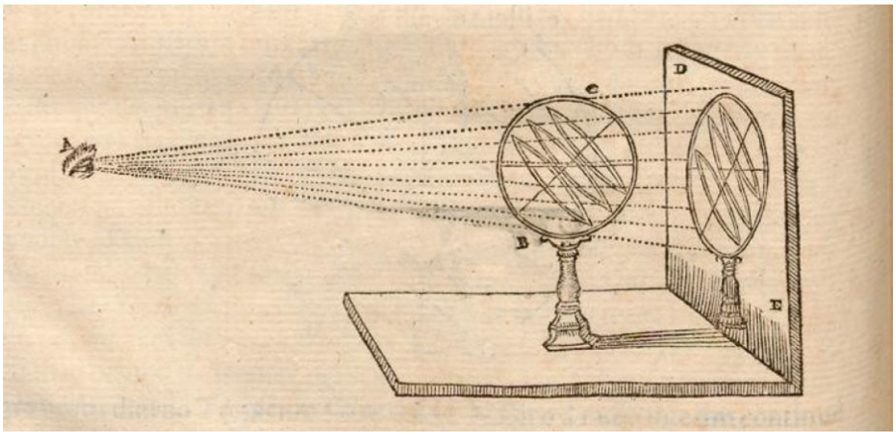

Figure 13 – E, Maignan, *Perspectiva Horaria*…, illustration for Propositio XVI

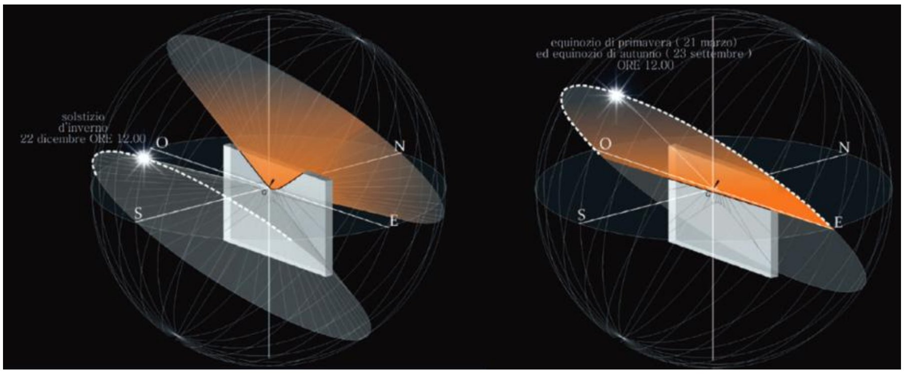

Figure 14 – Cones of light for calculating the lines of the sundials. Digital image by S. Perucci

In my hypothesis historical researches on gnomonics (more in general on light) have influenced the development of projective geometry, a proof can be found in the terminology adopted for this matter: for example the expression “projective star” belongs to the study of celestial phenomenon. The very word “focus” describes those properties of bends resulting from conic sections (ellipse, parabola, hyperbola), and it bring us back to the concept of light; maybe it was discovered because of practical experiments on parabolic mirrors: if rays of sunshine, parallel to each others, are reflected within a parabolic surface, they converge in a point called focus. In this regard, it is hard not to mention the Archimedes’ tale (287-212 a.C.) about concave glasses, used to set fire to enemy ships during the siege of Syracuse (212 a.C.).

A final remark about the connection between light, vision and geometry is combined with the history of the projection center: about this topic we can consider the use of the points of infinity as center of projection. The rays of sun can be considered parallel to each other [12], in this way they are able to produce shadows of objects in cylindrical projection, a good guide for the development of axonometry method in representation science [13].

3 Conclusion

The analogies in the structure between the two treatises about anamorphosis and gnomonics written respectively by J. F. Niceron and E. Maignan, suggest a common background of research. As experimented with the students of the “Blick Raum Bild” seminary at the TU Kaiserslautern, the use of light projection can be a working frame for the realization of anamorphic images. From a geometrical point of view, anamorphosis and sundials can be calculated adopting a similar method: conical sections of cone of vision and cone of light. This kind of observation suggests the important influence of studies on the light in the historical development of projective geometry. The points of infinity, concept that in the nineteenth century led to new forms of representation (axonometry and orthogonal projections in Monge method), are well represented by the shadows of objects projected by the sun light.

Finally we can argue that the concept of projection can be considered a common instrument for different disciplines, in our case optic and gnomonic, and the light as a clear representation for studying the physical behavior of this instrument.

Acknowledgments

Thanks to the Technische Universität Kaiserslautern for guesting me during my Phd researches, to the students of the “Blick Raum Bild” seminary and to C. L. for supporting me during my stay in Germany.

References and Notes

[1] VITRUVIO, Mario Polione. **I dieci libri dell’architettura, tradotti e commentati da Daniele Barbaro**. Venezia 1567, Libro IX, pp. 398-437.

[2] The word gnomonic derived from the greek word “gnomon” - γνωομονική (τέχνη) - that means “indicator”. A gnomon, also called “style”, is the stationary arm that projects the shadow on a sundial. The gnomonic is the science that explains how to calculate solar clock.

[3] NICERON, Jean François, **La Perspective curieuse, ou magie artificielle des effets mervellieux…** . Chez Pierre Billaine, Parigi 1638, tab. 24r.

[4] The lens in Plexiglas was milled in the Mechanical Laboratory of the Technische Universität Kaiserslautern (Germany) according to the 3d digital model, used also for simulating with renderings the correct operation of the device.

[5] DESCARTES, René. **Discours de la méthode pour bien conduire sa raison, et chercher la verité dans les sciences Plus la Dioptrique, les Meteores, et la Geometrie qui sont des essais de cete Methode**. Leida, 1637.

[6] According to the history, the first one who focused on refraction law was the Arab mathematician Ibn Sahl in a text written in 984 a.C., the first scientist who explained mathematically this law was Snel van Royen (law of Snell). The indexes connected to different transparent materials were established in the last part of the XIX century.

[7] The Greek word anamorphosis (ἀναμόρφωσις) is composed by the prefix ana- (back) and the suffix morphe (shape). The term describes the process in which an image can be distorted and recognizable only from a precise point of view or by using particular tools (mirror, lenses).

[8] In his treatise Niceron described three main types of anamorphic images: the direct one, in which figures become recognizable only from a precise point of view, generally oblique to the plane of canvas; the catoptric one, the case where the observer needs a mirror to see the correct image reflected, the mirror can have different shapes (cylinder, cone, pyramid); the dioptric one, if the image directly observed doesn’t appear to be deformed, but totally different if observed through a polyhedric lens put together inside a monocular.

[9] MAIGNAN, Emmanuel, **Perspectiva horaria, sive de orographia gnomonica tum theorethica tum pratica libri quattuor**. Romae : Typis, & expensis Philippi Rubei, Rome, 1648.

[10] The treaty is written in latin, the original sentence is: “Catoptricis ad Optica paululùm digredior, non propter argumenti affinitatem (quae nulla hic est) sed propter modorum operandi similitudinem in operibus licet diversis”. Perspectiva horaria, p. 438.

[11] For a general introduction to gnomonic consider: BOYD, Mark Lennox. **Sundials, history, art, science**. Frances Lincoln Ltd., London, 2006.

[12] Considering the distance between the sun and the earth and the different dimension of the two elements we can say that the projection of light made by sun is cylindrical, in reality the projection is a conical one but the divergence of rays is enough small (± 0,27°) to be consider irrelevant.

[13] For the relation between shadows generated by sun and axonometry consider: McGOODWIN, Henry. **Architectural shades and shadows**. Bates & Guild Company, Boston 1904.

[14] HEILBRON, John L.. **The Sun in the Church, Cathedrals as Solar Observatories.** Harvard University Press, London, 2001.

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[17] PERRUCCI, Salvatore. **Le linee del tempo, architettura gnomonica, geometria.** Phd thesis, Naple, 2014, not published.