LLULL, vol. 23, 2000, 599-642

FLORENTINE PERSPECTIVE AND THE DEVELOPMENT OF MODERN SCIENCE

JULIO ROBERTO KATINSKY
Dpto. de Historia da Arquitetura e Estetica do Projeto
Facultade de Arquitectura e Urbanismo da Universidade de São Paulo

RESUMO

Dois processos para obtenção da perspectiva exata, foram registrados na Renascença. O primeiro consiste na obtenção de figuras reproduzindo a profundidade, pela combinação de um plano vertical, um ponto de vista e um plano horizontal; foi descrito magistralmente por Leone Battista Alberti em 1428 em eu tratado De Pictura *—em latim— traduzido para o italiano pelo autor em 1436. O segundo, frequentemente chamado de perspectiva pelos pontos de distancia, so'foi publicado em 1580, mas se sabe que era praticado muitos anos antes. The second method usually called perspective by points of distance was published in 1580, though it had been used for many years before, as we know now.*

Antonio Manetti e Filarete, contemporaneos de Alberti, em seus escritos, reivindicam para o arquiteto Bruneleschi a precedencia da

ABSTRACT

Perspective in Renaissance was obtained by means of two methods, as found out by researchers: the first one, which consists of combining a horizontal plan, a point of view and a vertical plan, thus obtaining figures in three dimensions, was in 1428, masterly described by Leone Battista Alberti in his treatise De pictura, *translated from the latin original to italian by himself in 1436.*

The second method usually called perspective by points of distance was published in 1580, though it had been used for many years before, as we know now.Alberti's contemporaries, An-tonio Manetti and Filarete, in their writings, claim that architect Brunelleschi, by means of studies with plane mirrors, preceded Alberti in the discovery of perspective. Their evidences, however, are not entirely fullfilling.

Recibido el 25 de mayo de 1995

descoberta da perspectiva exata, em relação a Alberti, atraves de estudos com espelhos planos. Entretanto, esses testemunhos seapresentam incompletos.

Aqui se descreve um instrumento muito simples, inspirado nos autores citados, composto de espelho fixo e visor, onde se verifica que a caracteristica dos pontos de distancia é uma propriedade dos espelhos planos e, portanto é possivel deduzir as principais regras da construção da perspectiva exata, a partir de experiencias com espelhos. Reforça-se assim, o testemunho dos escritores mencionados. Em seguida procura-se expor algumas consequencias para a historia da arte e da ciência, que se pode extrair dessa verificação.

Inspired in the aforementioned authors, we introduce in this paper a very simple instrument which is composed of a fixed mirror, and a plate with an eye hole (a view-finder). This device enables us to verify that the points of distance characteristics is a property of plane mirrors, so it is possible, through experiments with mirrors, to deduce the principal rules of perspective, thus strenghtening Manetti's and Filarete's evidences. Furthermore we will try to prove that we may recognize, based on that verification, some important consequences for the history of art and science.

Palabras clave: Óptica, Geometría, Renacacimiento, Siglos XV-XVI.

We have definite proof that Florentine painters have made use of perspective since the beginings of the 15th century and that it was spread through all Europe along the second half of the century by German, Portuguese, Spanish and French painters, who appropriated its initial processes and developed them through the following centuries, coming to its utmost rigour and complete crystalization in the first half of the 19th century.

In the meantime, however, many painters among the most considered ones, have disregarded its well known and practised laws as an artistic process, bringing forth *anomalies* in relation to strict obedience to proportions, thus obtaining not defective works but, on the contrary, the intensification of intentions which they sought in their representation.

Thus, in Velasques, for instance, the subtle disregard to certain human figures accentuates the grandiosity which super-human personnalities required.

I recall specifically the portrait of Count-Duke Olivares, now in the Museum of Art of Sâo Paulo, painted in 1640, in which the powerful minister's figure, taken a little above natural proportions and making us look at it bottom-up, that is, in a position of inferiority to the represented object, has yet its head reproduced a little smaller than we could normally expect, forcing us unconsciously to imagine the figure of one of the most powerful men in the world, greater than we could consider if we did it only on an actual physical basis.

In this case, the painter, faithful to a psychological greatness —so to say— falsifies metric quantities, a trick that had, by the way, been used far away in the past, by artists of old mediterranean empires, to make their monumental sculptures.

This *disrespect* towards correct proportions is often recognisable in Goya, which led his academic contemporaries to criticise it as *errors of drawing*. Yet, the most obtuse observer can see that the picture —*The charge of mammelucos the second of may in Madrid*— is based, at least, on three Horizon-lines: the most evident is referred to the scenery foudation buildings. The second line is related to the mob which is in the second plan of the picture and the third one to the fighters of the first plan.

In the picture *The shooting of the third of may*, the luminous kneeling figure at the center, who is to be shot, is almost twice as tall as his executioners, leaden french soldiers. As it seems, the master artist was not affected by his contemporary academic criticizers, for in his *the deafman farm* (Quinta del sordo) he used again many alterations of the observer distances from the objects displayed in the same picture, thus obtaining a sensation of *strangeness* (human figures acquire a character of monstrosity in its very sense), which brings perplexity to critics even in our days.

Those paintings were made between 1810 and 1820 and very probably were not known by Gericault who, in 1825, painted *Medusa's raft*. In this picture, also, the raft, painted on a virtual horizon line, masses of water partially hiding this line and mixing up the referential of the picture, accentuate the vision of lurch and hopelesness which pervades the whole painting.

Those examples, all of them prior to 1830 and that we could display to exhaustion show us how was it that the great masters made use of perspective whithout letting themselves be dominated by a slavish attitude which, never-

theless, was the characteristic of european academic teachers. Yet, the great crisis of perspective as the *painter's science*, as a necessary aid, has happened with the discovery of photography.

With the diffusion and progressive improvements of photography, from the second half of the 19th century to our days, perspective has been questioned more rigorously, in a critical level and not only as an artistic and creative process, and the documentary research about its origins has also been made more carefully.

The book *On Painting* by Leone Battista Alberti, was considered, until mid past Century, the first one to expose the method of perspective and its discovery credited to its author, though Vasari, in his biography of the architect Brunelleschi, had, parentetically, commented on the precedence of his biographed in relation to Alberti as to the discovery of perspective.

The exhaustive philological work of the end of last century was, however, what has really revealed a whole complex of treatises and texts from as far as the XVth century that, until then, were in manuscripts, accessible only to a diminute number of scholars, for they were deposited in italian or other european libraries.

Since 1870, the treatise of architecture by Filarete and Lorenzo Ghiberti's *Comentarii* were made public; as well as the biography of Brunelleschi by one of his contemporaries, consensually believed to be Antonio Manetti.

In those texts, published with minutely critical remarks,an ensemble of indicatios arise, by which is clear that there was a preocupation of painters and artists of the *florentine quattrocento* with optics and mathematical adequation of painting to the represented reality. For instance, it must have been highly surprising to confirm that Ghiberti knew the great medieval scholars and scientists like Ibn Al Haitan (Alhazen), Vitello or Peckham.

In those texts, especially in Manetti and Filarete, reappears the revendication for Bruneleschi's authorship of the discovery of perspective and the sources on which Vasari's affirmations were based. So, many studies were made which proposed new interpretations of the process that culminated with the discovery of perspective, minds pending by turns for Bruneleschi and Alberti.

Among those studies, the works of Pierre Francastel and Alessandro Parronchi arise above all of them as specially remarkable for being based upon the architect of the dome of Santa Maria Dei Fiori. Nevertheless even these authors do not convincingly discern which is Alberti's and which is Brunelleschi's contribution.

The present study intends to attain the completion of those authors' theses, and furthermore, was originated by an attempt to make the study of perspective more intelligible for the beginners.

This study presents some experiments which reinforce the certainty which grants Brunelleschi with the precedence in the discovery of perspective. In this sense, it is a contribution to the knowledge of a decisive period of our modern culture, but it has furthermore some consequences at didactic level, for, in fact, it is possible to improve the teaching of perspective beginning with a more correct understanding of which we are doing.

Based in a simple device designed for this experiment, we propose two perspective methods: a optical-graphic due to Brunelleschi, and another one, purely geometric (and derived from the former), by Alberti.

Brunelleschi's Optical-Graphic Method

We are going to consider the texts contemporary to the artist, and that give him priority in the discovery of perspective.

The longest one is the text attributed to Manetti, where two little pictures elaborated by Brunelleschi are minutely described.

The first one was a square wooden board, whose sides measured 29 cm (half florentin *braccio*), and that was painted with a picture of the Baptistery of Florence (St Giovanni Church) as it would be seen from the central door of Santa Maria dei Fiori Church (which was then being built) and of the buildings that surrounded the place where the baptistery stays.

Manetti also says that the little wooden board had a hole in it, in a convenient position,whose diameter measured aproximately 4 mm on the side of the picture and was enlarged in the opposite face to attain 2.5 cm more or less.

The observer, taking the board by its reverse side and looking through the hole, should place a mirror, 14.5 cm high at a distance of one *braccio* (58 cm more or less), so he would have the impression of seeing the baptistery and the surrounding square from the central door of Santa Maria Church.

We must explain that Brunelleschi had fixed another mirror to the board, above the picture of the buildings, to obtain the reflection of the sky and of the moving clouds.

The second wooden board was much greater than the first one and represented the *Palazzo Vechio*, (seat of florentine government) and, partially the place in front of it.

Yet, unlike the other, it had no hole to look through, neither was there above it any mirror or picture representing the sky. The wooden board was cut at the height of the buildings' cimaises representations. These wooden boards were lost but the biographer states that he saw them and aknowledges their skilled and careful renderings. Yet suggestive as may be his descriptions of the boards, they give us only thin clues on how they could have been made.

Filarete's text, on the contrary, belongs to his Treatise on Architecture and begins with a description of the construction of perspective.

This description is similar to the construction presented in Alberti's book, so it does not throw any further light on what we already knew. Nevertheless, in the final paragraphs of that part, he points out that this process of perspective was created by Brunelleschi who developed it from observations with mirrors and invites the reader to make experiments with mirrors to sustain his reasoning [see annex 1]. Now, Alberti's method does not mention mirrors but establishes an analogy between the picture surface and a window.

We decided to follow the clue proposed by Filarete —even knowing that mirrors were known for thousand of years— and remmenbering the mith of Narcissus, who, bewitched by the reflection of his own figure in a quiet spot of a limpid brook, had grown roots, thus being transformed in a vegetable being.

Furthermore, at least in part of the Middle Ages, mirrors were explicit references to real knowledge: speculative knowledge (from speculus).

Whoever have dealt with mirrors knows that the *observation* camp changes if either we put them nearer or farther from us, or, if we incline them; therefore we have formulated the following hypothesis: to discover the laws of perspective, Brunelleschi should, necessarily, had fixed the position of the observer in relation to the mirror.

Yet, this fixed relation between observer and mirror needs a very precise control to be efficient: a control like that furnished by an *alidade*, for instance (in other words by the focus of an instrument of observation). In these conditions, we have built a wooden screen for a mirror, fixed and perpendicular to a table, and a viewer of paper board whose sides measured 1.5 x 8 cm in which we made a little hole of 4 mm of diameter; we fixed the viewer at a distance of 40 cm from the mirror and made the hole at a height of 6 cm. Over the mirror was placed a transparet plastic sheet. After that, we cut a cardboard in the shape of a square, whose sides measured 20 cm and with its diagonals also marked. One of the sides of this cardboard touched the mirror, horizontally and coincident with the mirror base; its surface contained the perpendicular that linked the center of the base of the viewer to the center of the viewer's image in the mirror.

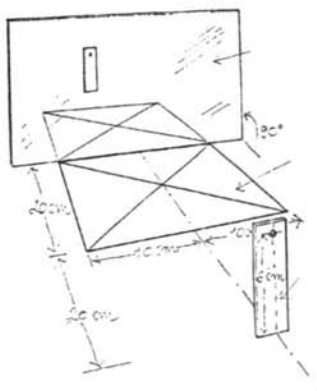


Figure 1. *Scheme of the mirror, square-draft, view-finder plate (40 cm far from the mirror) and their reflections - without scale.*

Then we put one of our eyes to look through the hole of the viewer, and trying to keep a strictly horizontal look, with a proper pencil we traced the image of the square in the mirror. Now, we know that a square is a regular figure, with sides and diagonal respectively equal. Nevertheless, with the described process we obtained in the plastic sheet a regular trapezium 2 cm high.

We lifted the cardboard for 3.5 cm, following the rear mentioned axis, and repeated the preceding doing, and obtained another regular trapezium, but its height was smaller. Then we separeted the plastic sheet from the mirror, taking care of drawing in it, beforehand, the image of the viewer and its hole, and fixed it in the drawing table. We put over it a transparent drawing paper and obtained the following results:

1. The square's sides perpendicular to the mirror and which in the image, correspond to the inclined sides of the trapezium, when prolonged, will meet in the image of the viewer's hole (whose diameter is more or less 2 mm). This was a very well known fact, registered already in Vitruvio's work.

2. The diagonals of the real and reflected trapeziuns, taken two at a time, and prolonged, will meet in the horizontal line which passes by the hole center, and their meeting point is aproximately 40 cm far from it (in truth, we noticed a difference of 2 mm). This was never registered before A.D. 1400 [see figures 1A, 1B].

For analogy's sake, we supposed that the same would occur with the cardboard sheet placed simmetrically in relation to the horizontal line and we drawed another square whose sides were 20 cm long, divided in 5 cm squares with their respective diagonals, and we went over the same proceeding again.

As it should be espected, we obtained one regular trapezium, divided into many trapeziuns, whose perpendicular sides directed themselves to the orifice image in the mirror and whose diagonals, prolonged, met in the afore mentioned points.

This is a bi-univocal relation, for, joining point D to the foot of the perpendicular (axis) in the center of the viewer and linking it until the line on which is based the larger side of the trapezium, we obtain the same 40 cm that define the distance from the viewer to the mirror [see figures 2 and 1].

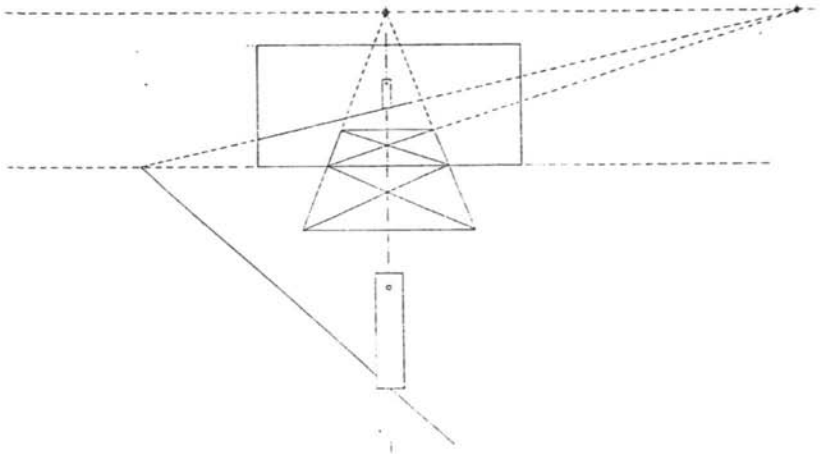


Figure 1a. *Graphic process showing how to obtain determinant points of the image in a plane mirror: distance and height of observer in relation to a supporting surface.*

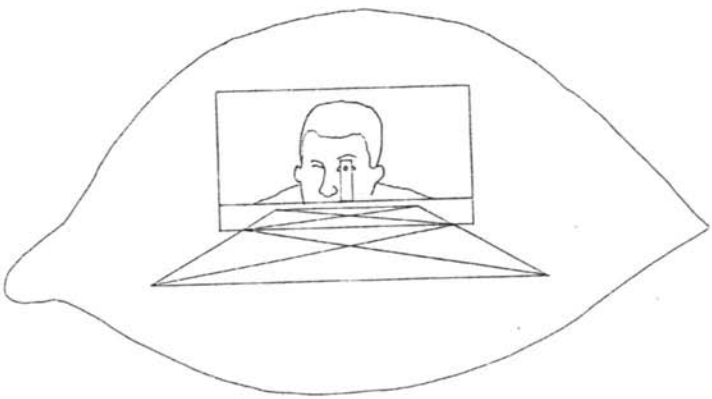


Figure 1b. *View through the eye-hole. The mirror reflects all luminous points. The observer shall choose the more relevant shapes.*

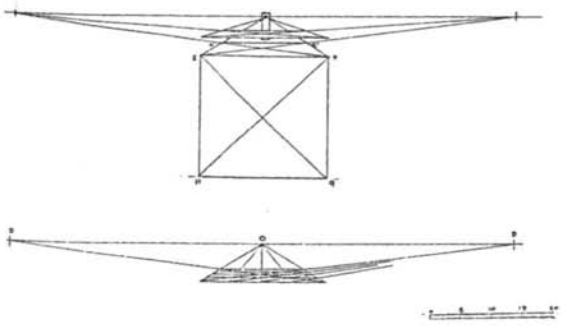


Figure 2. *Drawing of the trapezes obtained from the view —finder plate placed a a 6 cm height and 40 cm distance from the mirror (more easy to draw) and the extension of their diagonals—. Graphic scale.*

It is important to emphasize that those drawings are not mere pictoric conventions. In spite of having been obtained by a graphic artifice they are referred to specular images of their objects. The mirror does not know that it is reflecting drawings: it reflects a human work as faithfully as a flower or a stone.

We may say, therefore, that a necessary and biunivocal relationship is esta-blished for width, height and profundity of the image in the mirror and that is a valid relation, for instance, for a device used by millions of persons in the Earth, like the rear —view mirror of cars. The relations of distance discovered in our device we might apply to rear— view mirrors of cars (especially those in interior of vehicles) and could be used in their improvement, as they are now only modest pieces of mirrored glass. In a car the position of the observer is fixed, as well as the camp: only the images are in movement. Nevertheless it would not to be sensible to consider them *graphic images* [or mere symbolic forms without compromise with reality see figure 3].

Prof. Santillana, in another ensemble of considerations observed:

"We have, therefore, not one single invention but an ensemble of experimental inventions of enormous significance, whose importance may be put on the same level as the following invention, which will appear two centuries later: Galileus annouced his instrument as derived *from the most profound laws of perspective* and even if they lack propriety (at least in their modern sense) those are revealing words".

The truth is that not only the telescope but also all the dioptrics developed from the 17th century on derives from the discovery we are dealing with: perspective deduced from the reflection of mirrors may be understood as the foudation for the measure of luminous rays. In this sense, the very law of the velocity of image in mirrors, attributed to Descartes, may be seen as a simple corolary of the florentine discovery. In fact how can we establish the velocity of a body (real or virtual) if we don't fix lengths in time? Furthermore the lengths of luminous rays in convex and concave lenses (and in their combinations-optic instruments) were, first of all, established on a basis of the length of luminous rays in a plane mirror (see please the optical and astronomical instruments developed by portuguese navigators).

Lionello Venturi, in a study on Giotto, quoted by Flavio Motta, much righteously observes that the florentine painter, *'chiude una civilta pittorica che si occupa sopratutto di Dio e ne apre una nuova che si ocuppa sopratutto dell'uomo'* (closes a pictoric civilization which deals with God above all and opens a new one which chiefly deals with Man).

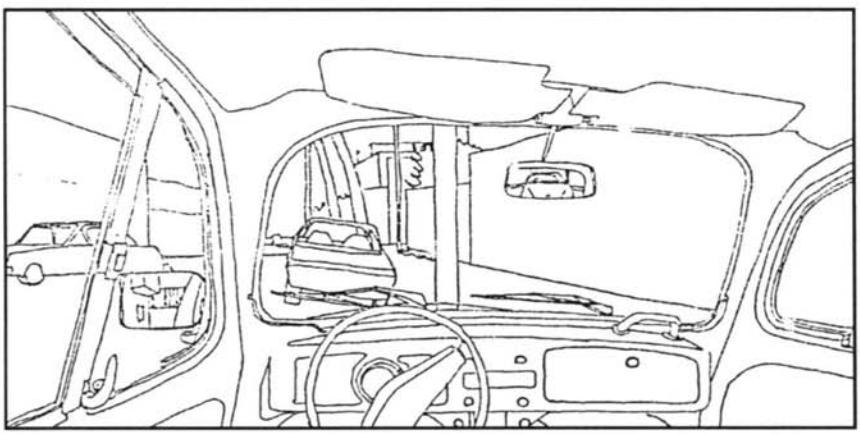


Figure 3. *Interior of a car with rear-view mirrors. Brunelleschi's rules are applied to mirrors with the following corrections: the surface of the inside mirror is not parallel to the observer's face. There is a deflection of aproximately 15 degrees in relation to a plan which is perpendicular to both observer and mirror (the horizontal plan) and a deflection of about 10 degrees in relation to a vertical plan.*

In other terms we may say, as Venturi did, that Brunelleschi ends with the studies on the optics oriented to sideral space, which is primarily based on angular distances and begins the research of an optics oriented to the accidents of our earthly world in which the important elements are land relief and measured distances. That is what Galileus remarked when he announced his invention of the telescope which, in his book Nuncius Siderius, he called perspicillum:

"it would be vain to specify how many and how important are the uses of this instrument, not only in view of earthen but also of maritim deeds. Leaving alone the earthen things I pointed out to the celestial ones".

If we find that those considerations are true, we may, then, with more precision agree with prof. Giorgio Santillana when he affirms;

"Brunelleschi must be considered the most creative scientist and artist of the *quatrocentto*, for in that epoch there was almost nothing that could be called creative science".

Brunelleschi's wooden boards

If we recall fig. 2 we must remark that there is an inversion of we normally see: the side EF in the drawing, larger than side GH is more distant from the observer O. Of course, it happens because EF is flat against the mirror so its size is not reduced. Size GH is in an intermediary position between the mirror and the observer. We have, therefore, not the real vision but, of course, its specular image.

To us, this seems to be the most important significance of the second mirror for the woodenboard of S. Giovanni [as related by Manetti, see fig. 4]. That is, we are not dealing only with an inversion from left to right, but also with an inversion of deepness —in other words— with the mirror and the hole in the woodenboard we obtain the real vision which, by the way, was confirmed by Manetti's description. Otherwise, we may say that the woodenboard becomes transparent by the hole and the second mirror.

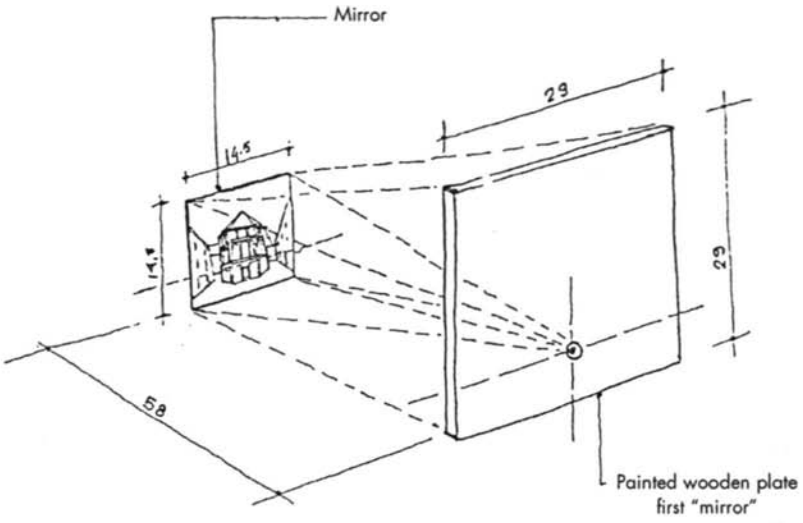


Figure 4. *Sketch of the wooden plate of the S. Giovanni church (Florence Baptistery) ad its mirror.*

Then we can say that to look through the hole in the mirror is like seeing the rear side of the wooodenboard. In an exercise of phantasy, let us imagine that over the smaller mirror there is a light sensible pellicule and the image of S. Giovanni that it reflects may be fixed in it permanently. We may then transfer the mirror to a place behind the woodenboard (which is now transparent) in the established distances, i.e., one *braccio* (more or less 58 cm) from the observer to the mirror, and one *braccio* from the mirror to the board. Then we may consider the board as being a mirror and the polished silver skyplate as well as S. Giovanni's Square, as being specular images, built entirely by graphic means of lines and colours [see figure 5].

Furthermore, we may propose a probable scale for the drawing on the woodenboard, that is 1/8" for 2 florentine *bracci* or more or less 1:400 in metric system. This scale reduces the baptistery figure aproximately to 9 cm width, which also agrees with Manetti's description that qualifies the drawing as an *excellent miniature*.

To believe in those considerations on the scale of the drawing we must previously agree that Brunelleschi himself not only made the painting in the

woodenboard in this previously decided scale but also had already defined the board for the drawing, for whatever the scale of the drawing may be, the board size is reduced to a half when placed at a distance of a florentine *braccio*.

We must remark that there is nothing strange with this hypothesis because all draftsmen adopt for their drawings, almost unconsciously, the scale most convenient to their bases. In the present case it would be enough to choose a scale which could reproduce the relation, by means of the two mirrors, of the visual cone.

Nevertheless it is worthy of notice that, in spite of his acurateness, Manetti's description on that point is not particularly precise, which leads us to suspect that he did not thoroughly understand the constructive and ideological conclusions of Brunelleschi's experiment, that is, why Brunelleschi making a hole in the woodboard and using the mirror, with a simple movement of his hand, he could demonstrate to his friends, that he could build, so to speak, in laboratory, an image entirely faithful to the image everybody could see from the door of the cathedral.

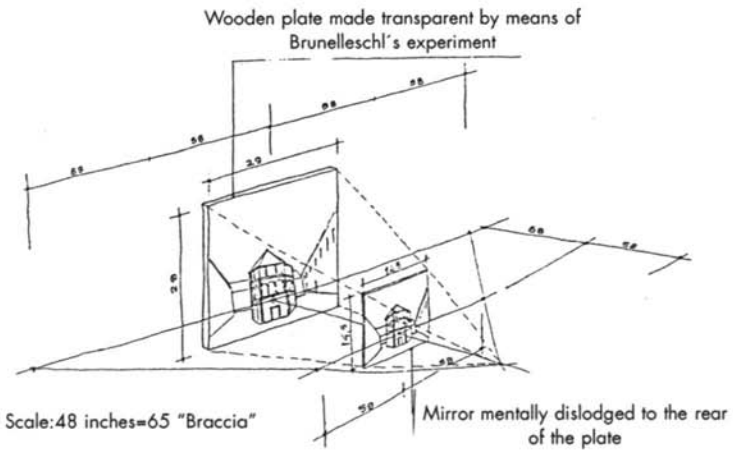


Figure 5. *Imaginary representation of the wooden plate and mirror in the experiment of Brunelleschi.*

As for the second board, the one that represents the *Palazzo Vecchio* and the *Piazza della Signoria*, Manetti suggests that because of its dimension it could not be possible, with a hole and a mirror, repeat the experiment of the baptistery. Yet, what would be the meaning of repeating the experiment? To prove the draftsman's ability? He could prove his ability in a more compensating occasion: for instance in the context to which he applied in competitions held in Florence in those days. We prefer althogether another interpretation, which is: once the validity of the perspective-laws had been proved with the first board, the second one would be the perspective construction with the total inversion already established, id est, the direct drawing in the board would represent the normal vision that we have of the palace from the point indicated by the historian.

It would also be useful to demonstrate the universality of the discovered laws, for the palace is assymetric itself, with its tower and one of his facades presenting many distortions.

Thus the two boards complement one another, each with its specific objective and, in a certain sense, each one is necessary and sufficient. The description of the second board, nevetheless, does not allow us to specify the scale in which it was built.

These conjectures are reinforced not only by our own device, which gives us a strong conviction, but also by a preparatory draft by Paolo Uccello. This draft is called *sinopia* in italian and shows a basic trellis with its perpendiculars converging to a central point and the diagonals converging to two points placed on an horizontal line which passes by this central point. We are speaking of the *sinopia* for the Nativity of S. Martino alla Scala Convent, published by Parronchi [see figure 6].

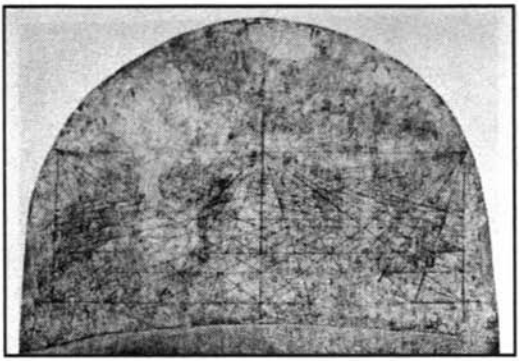
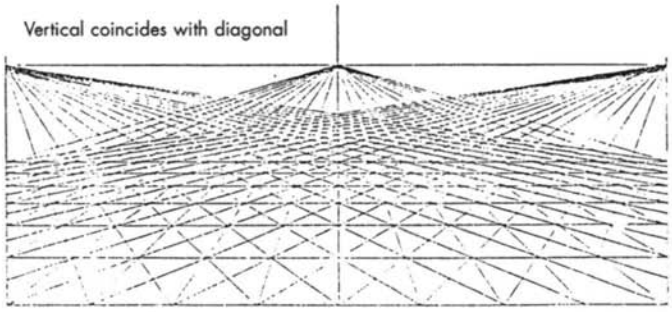


Figure 6. *Paulo Uccello 'sinopia' of the St. Martino alla Scala foto: Bardazzi fotografia – Firenze.*



Paulo Uccelo's reconstitution shows us a dubious character: the outside diagonals coincide with the vertical lines parallel to the picture presenting the same degree of indetermination which is a characteristic of the central perpendicular in the panel.

Alberti's geometrical method

We have already noticed that there was a non-explicit resistance from european painters in accepting perspective absolutely, and how this resistance increased until, at the end of the 19th and beginning of 20th centuries pers-pective was apparently and thoroughly rejected. Furthermore it seems that there

was another type of opposition coming from scholars not necessarily painters, relative to scientific (or so called scientific) foundations of perspective. This opposition still appears very vigorously in Vasari, in Paolo Uccello's biography. The fact is that Florentine art suffered a strange and disquieting trial, derived from the work of Brunelleschi and his mates: Masaccio, Ghiberti, Lucca della Robia, Paolo Uccello. In fact Giotto was confronted by these artists inside the very epistemological universe that he had built. In my opinion, Filarete displays this dilemma with great acumen when he registers the following paragraph in his Treatise:

"I believe that up to now you have understood how the plan was made.

I understood but I would like to make one, practically. Tell me, then, why these little squares are not squares.

The reason is because you see that in the plan; if you saw it in front of your eyes they would look squares to you".

"You can say that it is false, for it shows you a thing that is not. This is true; nevertheless it is true in drawing, for drawing itself is not true but a demonstration of the thing you [are] drawing or what you wish to show" [see annex 1].

The charges against Brunelleschi, in the first years of the century, became more and more violent. In 1425 the poet and designer Giovanni di Gherardi da Prato presented forth some alternatives for the construction of the dome of Santa Maria dei Fiori, in opposition to the project designed by Brunelleschi and Ghiberti that had won the public competition.

Di Gherardi also wrote a sonnet whose modern translation made by Parronchi may be understood as follows: *(Brunelleschi), poor man, at the level of animals, ruthless, ignorant, knowledge-missing, you intend to make visible to others what nobody is sure of, but your tricks are devoid of substance.* On the contrary to the *poet's* wishes, a little time after that, in 1426, the title of *inventor of the dome* was granted to Brunelleschi. This, however, was not the only attack made against the architect. Santillana cites a charge that calls his geometry a *false and mendacious* one.

Brunelleschi's answer to the aforesaid sonnet was terse:

"Ogni falso pensiere non vede l'essere
che l'arte da, quando natura involа"

(Every thought untrue does not see the being, what is given by art, when nature hides).

This verses only reasseverate the memory-specifications of the project for the dome, written some years before and whose final words don't give place to doubt: describing minutely the construction of the first fifteen meters in height of the double dome, he finishes the specifications with the following words:

"The dome must be built as was said before, until the maximum height of 30 *braccí* (more or less 17 meters) but with the scaffolding in the way that will be advised and decided by the same chief builders who will make the walls; above the 30 bracci everything will have to be planned again because in brick laying, practice will teach what shall be done from then on".

Those texts, from our point of view, are the justification not only of a specific situation but also of a new way of working with knowledge, a way already described in the famous paintings, but we may as well understand that it called for deep reactions which would not be motivated only by professional and personal envy or by opportunism.

In truth all of an epistemologic structure was being checked. This is, at least, what we may deduce from the study made by Frederick Antal when he tried to explain the extraordinary plastic incompatibility between two pictures painted at the same time, in the same town, by two painters both acknowledged as exceptional ones: Gentile da Fabriano (who still then used gothic plastic elements) and Masaccio, whose *naturalism* foretells the Renaissance.

It is in this context that we think Alberti's book *della Pittura* must be examined. Some modern scholars are inclined to attribute to the book the mere condition of a register of ways of perspective drawing, be then Brunelleschi's or of the ones of the various painter's *ateliers* of that time. Yet the book itself does not convey to us those intentions. First of all, it can't be accepted that Alberti would write his book in latin, that is, for his contemporary scholars all around Europe's learning centers and that he would claim the autorship of an innovation that was not his. In this sense, the commentaries in the american translation by John R. Spencer and in the brazilian translation by A.S. Mendonça only reinforce the conviction that Alberti was in his latin treatise, annoucing in his drawing method of perspective, an invention of his own. It's Alberti himself, who in his Treatise's first book declares incisively:

"The centric point being located as I said, I draw straight lines from it to each division placed on the base line of the quadrangle. This inscribed line indicates to me in what way, as if looking into infinity, each transverse quantity is altered visually.

Here some would draw a transverse line parallel to the base line of the quadrangle. The distance which is now between the two lines they would divide into three parts and, moving away a distance equal to two of them, add on another line. They would add to this one another and yet another, always measuring in the same way so that the space divided in thirds which was between the first and second always advances the space a determined amount.I can say those who would do thus, even though they follow the good way of painting in other things, would err. Because if the first line is placed by chance, even though the others follow logically one can never know certainly where the point of the visual pyramid lies. From this no small errors arise in painting. Add to this how much the reason (of such painters) is faulty when the centric point is placed higher or lower than the height of the depicted men".

(from Spencer's translation p. 56 and 57).

Alberti, therefore, makes a net distinction between his perspective method, that as we will see, is rigidly geometric, and the merely empiric method used in his contemporary *ateliers*. To Alberti's method a transparent frame placed at given vertical and horizontal distances from the observer is enough, and the checkered floor square meets the perpendiculars to the frame in its base line establishing the widths in real size [see figure 7]. Those points, once we link the meeting point of the *centric radius* with the transparent frame (perpendicular to the square that contains the eye) give us the reductions of the widths in relation to profundity.

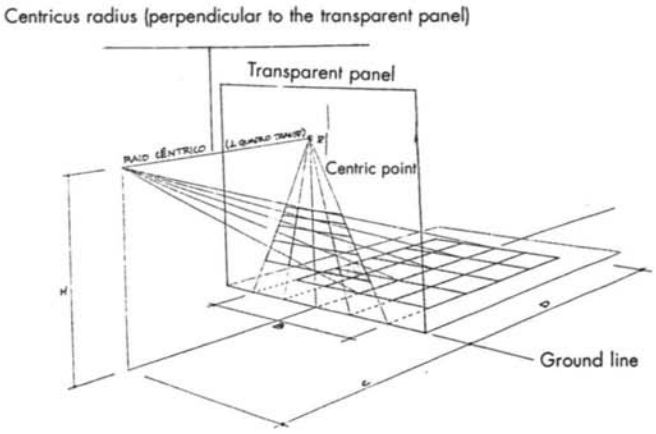


Figure 7. *Alberti's sketch of perspective construction. According to it, perspective can be understood, analogically, as a pyramid section, similar to the conic sections which were studied since Archimedes at least. This process, nevertheless, makes us easily loose a valuable reference of tridimensional space.*

Figure 7a. *Geometric deduction of width in perspective triangle (by A.C. Vasconcelos).*

To find the exact position of these profundities (which florentine painters since Giotto had already discerned empirically) Alberti uses the Thales theorem on the proportionality of similar triangles. This solution, demonstrated by means of Euclidian geometry could be better accepted by his contemporaries than Brunelleschi's method (that depended on an *illusion* that is the mirror's image).

That's why, in our opinion, Alberti's method was acknowledged by Filarete, as didactically less subject to controversies, though he insisted in the precedence of the great architect, his close friend.

Now, if in Alberti's latin version of his treatise there are only two references —indirect— to the optical method, in the italian translation, made by Alberti himself, there is a prologue where he insistently asks for Filippo's commentaries:

"May it please you, then, to read me with diligence. If anything here seems to you to need emending, correct me. There was never a writer so learned to whom erudite friends were not useful. I in particular desire to be corrected by you in order not to be pecked at by detractors" [op. cit. p. 40].

Now nobody asks for a critical reading of a text by someone who does not deal with its matter; so Alberti really wrote the book, in a first instance, to his learned contemporaries and in the book he states the originality of his method. Nevertheless, we must acknowledge that, skillful and intelligent as his process may be, it is nothing but a didactic simplification of Brunelleschi discovery and it derives directly from the observation of the afore mentioned wooden boards.

The two indirect references to Brunelleschi's method, found in Alberti's book are:

1. Book one,when he introduces the line of horizon, or in his own words:

"This being done, I draw transversely in the quadrangle of the picture a straight line parallel to the base line, which passes through the centric point from one side to the other and divides the quadrangle. Because this line passes through the centric point, I call it the centric line. For me this line is a limit above which no visible quantity is allowed unless it is higher than the eye of the beholder. Because of this, depicted men placed in the last squared *braccia* of the painting are smaller than the others. Nature herself demonstrates to us that this is so. In temples the heads of men are seen to be almost all on the same level but the feet of the farthest correspond to the knees of the nearest" [see op. cit. p. 58].

As we can see, he uses the *centric line* only as a reference, because his method doesn't need it. To him, it's enough the base's line and the centric point. Pier della Francesca in his treatise *Prospectiva Pingendi* that derives from Alberti's treatise never uses the *centric line*. On the contrary in optical method the centric line is essential.

The second reference to the Brunelleschi's research, we can find in Book two:

"A good judge for you to know is the mirror. I do not know why painted things have so much grace in the mirror. It is marvellous how every weakness in a painting is so manifestly deformed in the mirror. Therefore things taken from nature are corrected with a mirror. I have here truly recounted things which I have learned from nature" [see op. cit. p. 83].

Both references reduce Brunelleschi's optical-geometric method to a modest instrument of verification of Alberti's geometric method, lessenning its real importance. Yet, Alberti's own monocular *pyramid* derives from Brunelleschi's paintings as we have demonstrated. Even if this is not the place for that discussion, Alberti's discovery could never have been derived from the daily experiments of florentine studios and their narrow practical purposes. On the contrary, however, St. Giovanni's board and mirror, may consistently be associated to optical devices of the epoch, like the *alidade* and a deep concern and reflexion about the phenomenon of vision.

On this subject we advise the reading of our former studies, quoted in the bibliography, as well as the english translation of one of Alberti's variations of his own latin texts, in which he explicitly disregards optical discussions which were being made in his time (see Spencer trans. p. 46 and 47). And as long as Alberti strongly advises painters to learn geometry (which, nevertheless, must be seen from a painter's standpoint, that is only on practical usage), ten years later, in 1446, Ghiberti compounds his third commentary, trying to connect perspective to medieval optics. The same may be said of Piero della Francesca, for, in his book besides geometrical figures he still insists in the presentation of *theorems* of *The Optics* of Euclides.

But, if Alberti consciously reduces perspective down to a pictorial instrument, which is adopted in all academies as something complete, and thus he diminishes one of the most revolutionary of florentine discoveries, we cannot suppose that this attitude was born from lack of understanding. He himself left registered his perfect knowledge of the florentine discovery in these words:

"Truly, if ever this was written by others, we have dug this art up from under the earth. If it was never written, we have drawn it from heaven" [op. cit. p. 84] (note almost the same words in Manetti text).

Perspective is not only the inflexion point between mediaeval and modern optics. It is also the first unquestionable rupture with Euclidian geometry. In greek geometry, the method of resolution of tridimensional space problems consisted in dividing that problem into problems of bidimensional space, resolve them in this space, and by means of aggregation, reach the solution in the tridimensional space. It must be observed that Euclydes' postulates refer, all of them, to bi-dimensional space. Perspective presents itself as its opposite: the solution to be found is valid only as long as a tridimensional one, be it in Brunelleschi's mirror process or in Aberti's process of conjugation of an horizontal with a vertical plan.

Alberti's solution has, maybe, the merit of showing that this new attitude does not deny the Euclydian geometry but that it faces problems in a tridimensional space, impossible to be resolved by the traditional way of aggregating partial connected solutions. In other words, if we associate one paper sheet to an Euclydian plan, all figures contained in it will be under the principle of identity: each point will be identical to itself. Or, in modern language, the figures are in their actual size. If we put a figure in perspective on the same sheet, this will not happen: in that case each point is at the same time the image of infinite points of the tridimensional space —that is— in perspective plan the characteristics of the Euclydian plan of identity and of unicity of points do disappear. In this sense, even if it was not clearly aknowledged by scholars of the *400*, perspective was the first step for further developments of projective and descriptive geometry.

In short, many modern historians tried to connect perspective to optics; yet most of them tried to establish a linear relation, so to speak, between medieval optics and Brunelleschi's experiment. Now that linear, automatic relation does not exist. We have to recognize an innovation in the optical proposition, that, though not having been of immediate interest for the great medieval scholars, were, on the contrary, an enticing problem for european painters, specially florentine artists, since, at least, Giotto's times. This problem is the relative distance of the figures in the plan.

Brunelleschi's solution, therefore, in view of its inneditism must have deeply had shocked even those florentine scholars, who were the most learned

and thoroughly used to the Trivium and Quadrivium with their demonstrations through axioms, theorems etc. The boards made by the great master did not look like a demonstration to them, but probably they appeared more like manual skill, market-tricks (our own modern vision of those boards, after three hundred years of *laboratory experiments*, are, althogether, completely different). That was, perhaps, the reason why Gherardi di Prato, in his sonnet, tried to demoralize Brunelleschi, exactly for one thing the great architect had not, id est, an academic universitarian upbringing. Let us recall his eloquent verses:

"Poor man at the level of animals"

that is member of a guild, like a team of horses that make things whithout knowing why

"Ruthless ignorant science missing"

sciences that are taught at the Colleges

"You try to make visible to others that about which we are not sure, but those tricks appear devoid of substance".

Here, if in a way the dialectic discourse is well equipped, we also see a thorough incapacity to understand the proposed experiments. The same incapacity that, two hundred years later, the learned astronomers dominated by the greek notions of sidereal bodies made of incorruptible matter, different from this inferior world, refused to acknowledge the topographic accidents of the moon displayed by Galileus' telescope.

In that sense, Alberti's book was an irrefutable reasoning for those accustomed to exercise syllogisms and familiar with the most important theorems of euclidian geometry. That was how a man educated in the best italian universities guaranteed (and contributed) for the discovery of a brilliant, no doubt, but, even so, a simple *craftsman*. Hence, maybe, Alberti's undoubted prestige which lasted until our days. It is true that the italian translation of Alberti's treatise was made only in 1436, when the most impressive dome of Europe, since Saint Sophia, was already finished, though it is most curious that the author of the dome had to submit himself to participate of a second contest in order to see approved, ten years later, in 1446, his project for the lantern, conclusion of the same dome. And it is also strange Alberti's attitude of hiding his illustrious predecessor's experiments, as well as his recommendations that painters should

patronize litterary persons in order to learn beautiful things (why not the opposite?). This episode may lead us to imagine a not minded dispute between canonical and corporative knowledge, probable reason why Brunelleschi's set of friends did not greet Alberti's book too much enthusiastically, and we may even underline a bit of irony in Filarete, when, in the prologue of his book, he tried to approximate Alberti's treatise on architecture to that of Vitruvius', when it was well known that Alberti himself criticized harshly the roman architect.

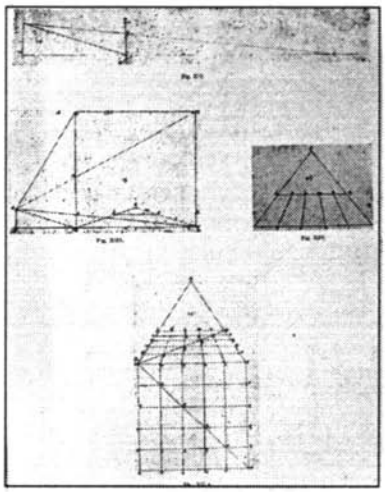


Figure 8. *Piero della Francesca's perspective studies (s. 1470). Piero della Francesca's construction obeys exactly to Alberti's lessons. The line of horizon -'centric line' does not appear in them. Nevertheless, the perspective diagonal always is the specular image of all square's diagonals.*

Vasari himself, so identified with the Medicis, was clearly reticent towards the merits of our *uomo universale,* name with which european humanists liked to call Alberti. Yet the convenience of Alberti's process was thoroughly acknowledged by italian artists, beginning with Filarete himself, as we have already said.

All those facts would lead to restrict Brunelleschi's concerns and processes to a very reduced circle of wise artists, and we find very few registers of them in his epoch, even if they were exercized in private, as, for instance, in

the sinopia of S. Martino. The method of the *points of distance* according to Parronchi, was made public only through Vignola's work —apart from whatever optical reference— almost two hundred years later. We, who live another phase of processes of knowledge, even giving the deserved credit to the historical and episodical importance of Alberti's propositions, we consider this critical revision absolutely necessary for it gives us more ample opportunities to evaluate past and present more adequately and improve learning methods.

Conclusions

1. It is possible to deduce perspective laws graphically from the study of reflection of plan mirrors through a very simple device composed of a fixed mirror, a sheet of transparent plastic and a viewer (alidade).

The device which we propose reinforces the conviction of Brunelleschi's precedence in the discovery of the perspective as was registered in the books of Manetti and Filarete.

Alberti's geometric perspective method presents itself as a skillful simplification of a remarkable optical discovery but it impoverishes the universe of concern of our contemporary artists. We also suggest corrections in these chapters of history of science and art.

2. It is desirable that, together with *Alberti's window*, the plan mirror with its viewer to be introduced in art schools, because the understanding of the method becomes more adherent to the origin of the discovery, making it less fortuitous.

In fact when perspective was discovered, in the beginning of the 15th century, almost all painters artists and architects were men who had had a corporative education. This education had the remarkable merit of unite, in the individual both intellectual and operational development, that is, the three fundamental degrees —apprentice, official and master— were connected by a progressive and long apprenticeship in the daily dealing with their trade problems. In other words there was not such an accentuated disproportion between *conceiving* and *making*.

It is well known that the intense interchange established in the previous centuries and that was increased in the 15th century, admitted new proceedings, unforeseen by the corporative rules, each time more rigid. Those corporations were considered by the rulers (and in fact so they were) an obstacle to those new possible and desirable developments.

This is how, coming from the most detached among the artists of the 15th century, we see the reivindication emerge that painters' and sculptors' activities should be considered as *liberal arts* and not *mechanic jobs* anymore. Ghiberti's *Commentaries* leave no doubt about it.

This way, nevertheless, was not free from confusion. If the aforesaid proposition were accepted, architects, sculptors and painters (of big pictures) would be liberal artists. What about the engravers who, in the second half of the century, had their number significantly increased would they be liberal artists or *mechanical workers*? And ceramists? Lucca della Robia was recognised as an artist by Vasari, but as an artist-inventor of new enamels for his own ceramic-works as well as a collaborator to great architects of his epoch (whose work he decorated with enameled terracotta highreliefs)? Hence comes the *functional* valorization of the *genius* as Hauser shows.

For, if in a way, the genius exaltation, exposed with utter clarity by Vasari in his renowned work, supported the social and political erosion of the corporative system, otherwise it opened possibilities to non canonic activities (like, for instance the first modern *engineers*). The 15th and 16th centuries, minding the progressive weakening of corporative instruction essayed to substitute it for the incipient Academies. We must, in this sense, understand the enormous effort that the florentines put out and which is materialized in the many treatises that flourished in the second half of the 15th century. Those treatises had the didactic efforts as his chief aim, but the Academies, that should have their greater development in France, in the 17th and 18th centuries, inherited one of the worst aspects of the corporations, that is, the *specialized knowledge.*

In fact the Academies remained as isolated institutes and it is in this context that we can understand Alberti's proposition of an optics specialized to painters, that is the *prospettiva pingendi.*

It is curious to notice that, even with the remarkable success of French academies (that served as models to all European and American academies),

the painter Goya, still in *ancient regime*, in 1792, and still a well appreciated painter of spanish court, left us a passionate statement against academic teaching of his time. Even so, Academies resisted, with their teaching methods which were preferentially operational, until the end of the last century. From then on, the constant efforts of european and american artists have been directed to find alternative methods for artistic teaching.

We think that an history of art, which is not derived from regional or local objectives, but is oriented by an attitude which we will consider as scientific, will add to the steps already taken that lead to correct and eliminate obstacles to man's full artistic development. This investigation intends to go this way. It deals not, therefore, with another device to *simplify* operational processes but, on the contrary, an instrument to dote pupils with a more solid understanding of those artists which we call *renaiscentists* and at the same time, re-establish an eventual link between modern optics and artistic operations.

3. Teaching of perspective should not be restricted to schools of art, but should be introduced as a compulsory passage from the Euclidian geometry to other geometries.

The teaching of perspective by means of a mirror, faces pupils with a preliminary fact: the scale, or relation between an object and its image, starting with the distance of the observer with the mirror.

It also brings up the materialization of Huyghens' principle, that is, each point in space that reflects light, behaves like a light emitter in all directions.

We must acknowledge that drawing, optional in brazilian high-schools, should be again a part of the permanent program, because we are convinced that, if correctly administered, it develops imagination which is a must in modern daily life.

Annex 1

The Life of Brunelleschi by Antonio di Tuccio Manetti Introduction, Notes and Critical Text Edition by Howard Saalman The Pennsylvania State University Press 1970 p. 42, 44, 46 with the permission of *Penn State Press*.

During the same period he propounded and realized what painters today call perspective, since it forms part of that science which, in effect, consists of setting down properly and rationally the reductions and enlargements of near and distant objects as

perceived by the eye of man: buildings, plains, mountains, places of every sort and location, with figures and objects in correct proportion to the distance in which they are shown. He originated the rule that is essential to whatever has been accomplished since his time in that area. We do not know whether centuries ago the ancient painters —who in that period of fine sculptors are believed to have been good masters— knew about perspective or employed it rationally. If indeed they employed it by rule (I did not previously call it a science without reason) as he did later, whoever could have impartedt to him had been dead for centuries and no written records about it have been discovered, or if they have been, have not been comprehended. Through industry and intelligence he either rediscovered or invented it.

Although he was preeminent over many otherts in many things and consequently refined his own and the following century, he was never known to boast or praise himself or vaunt or laud himself by a single word. Instead he proved himself by his deeds with the opportunities that came along. Unless greatly provoked by insulting or disrespectful acts, he never became angry and was amiable to his friends. It gave him plea-sure to commend those who merited it. He willingly instructed those he thought wished to be instructed and who were capable of instruction. He was very skillful and discerning in that as he was in other things.

He first demonstrated his system of perspective on a small panel about half a *braccio* square. He made a representation of the exterior of San Giovanni in Florence, encompassing as much of that temple as can be seen at a glance from the outside. In order to paint it seems that he stationed himself some three *braccia* inside the central portal of Santa Maria del Fiore. He painted it with such care and delicacy and with such great precision in the black and white colors of the marble that no miniaturist could have done it better. In the foreground he painted that part of the piazza encompassed by the eye, that is to say, from the side facing the Misericordia up to the arch and corner of the sheep (market), and from the side with the column of miracle of St. Zenobius up to the corner of the straw (market), and all that is seen in that is seen in that area for some distance. And he placed burnished silver where the sky had to be represented, that is to say, where the buildings of the painting were free in the air, so the real air and and atmosphere were reflected in it, and thus the clouds seen in the silver are carried along by the wind as it blows, Since in such a painting it is necessary that the painter postulate beforehand a single point from which his painting must be viewed, taking into account the length and width of the sides as well as the distance, in order that no error would be made in looking at it (since any point outside of that single point would change the shapes to the eye), he made a hole in the painted panel at that point in the temple of San Giovanni which is directly opposite the eye of anyone stationed inside the central portal of Santa Maria del Fiore, for the purpose of painting it. The hole was as tiny as a lentil bean on the painted side and it widened conically like a woman's straw hat to about the circumference of a ducat, or a bit more, on the reverse side. He required that whoever wanted to look at it place his eye on the reverse side where the hole was large, and while

bringing the hole up to his eye with one hand, to hold a flat mirror with the other hand in such a way that the painting would be reflected in it. The mirror was extended by the other hand a distance that more or less aproximated in small *braccia* the distance in regular *braccia* from the place he appears to have been when he painted it up to the church of San Giovanni. With the afore mentioned elements of the burnished silver, the piazza, the viewpoint, etc., the spectator felt he saw the actual scene when he looked at the painting. I have had it in my hands and seen it many times in my days and can testify to it.

He made a perspective of the piazza of the Palazzo dei Signori in Florence together with that is in front of it and around it that is encompassed by the eye when one stands outside the piazza, or better, along the front of the church of San Romolo beyond the Canto di Calimala Francesca, which opens into that piazza a few feet toward Or San Michele. From that position two entire façades —the west and the north— of the Palazzo dei Signori can be seen. It is marvelous to see, with all the objects the eye absorbs in that place, what appears. Paolo Uccello and other painters came along later and wanted to copy and imitate it. I have seen more than one of these efforts and none was done as well as his.

One might ask at this point why, since it was a perspective, he did not make that aperture for the eye in this painting as he did in the small panel of the Dnomo of San Giovanni? The reason that he did not was because the panel for such a large piazza had to be large enough to set down all those many diverse objects, thus it could not be held up with one hand while holding a mirror in the other hand like the San Giovanni panel: no matter how far it is extended a man's arm is not sufficiently long or sufficiently strong to hold the mirror opposite the point with its distance. He left it up to the spectator's judgment, as is done in paintings by other artists, even though at times this is not discerning. And where in the San Giovanni panel he had placed burnished silver, here he cut away the panel in the area above the buildings represented, and took it to a spot in which he could observe it with the natural atmosphere above the buildings.

Filarete's Treatise on Architecture

Being the treatise by Antonio di Piero Averlino, Known as Filarete, Translated with an Introduction and Notes by John R. Spencer New haven and London, Yale University Press, 1965, with permission of Yale University Press.

Explicit Liber Vigesimo Secundo. Incipit Liber Vigesimo Terzo.

You have been able to understand the principles of drawing from the preceding book. Now in this one I should like to show you how these lines are extended to make a building or any other thing located in its place with its rule on a plane (surface),

whether figures or animals. Now you should pay attention and open the eyes of your intellect, for what I have to say is subtle and difficult to understand. When you wish to build a building, it is necessary to prepare the things needed for its construction. When they are prepared, the foudations are dug, and then arrangements are made for walling it up. We will do the same with this. As it is necessary to have a site in order to build and to dig the foudations, so we too will first make the site in which we wish to make our drawing. First of all our site must bne a plane that is made by rule. Then the things drawn here will also be according to a rule and measures. As I have said, be attentive.

First, in order to make this plane it is necessary to have the two aformentioned instruments. Without them nothing can be done. They are, as I have said, the compasses and the square as well as a ruler. With the compasses you measure every surface and with the square or rather with the ruler you will rule everything that you have measured with the ruler.

Tell me why is this called a compass (sesto)?

Because it goes six times around a circle made by itself without closing or opening its legs. The square (is so called) because a square is made with it by turning it four times on a linear drawing on any other thing that you want to make square. Everything that man wishes to do must be done with a certain principle and (in a certain) form. The thing begun (must be) continued with the order it deserves. Therefore, we first pretend to stand at a certain window through which we see everything that we wish to describe and draw on our plane.

With a pair of compasses,make four equidistant points (Fig. fol. 177v). Join them together with straight lines and make a square You can do it with a square and make it whatever size you please. When this is done, you decide for yourself how large you want the figures to be. As you have learned before, and it is also a maxim of the philosophers, man is the measure of all things. Take a third part from the figure you want to make; this will be a common braccio, for almost all men conform to a rule. When you have done this, take one of these parts, that is one of these braccio, with your compasses and divide the base line of your window. Then along the perpendicular lay out three [of these measures] from the bottom line. At this height draw a very fine line. Then make a point either above, below, or exactly on this line, either in the middle or at the side. If you want the things to appear head-on, place your point in the middle of this line. As I have said, they will be more full-face and more pleasant. However, put it wherever you wish.

Now you must consider how far away you wish to stand to see your work. You should know that the closer you stand the larger the things will appear, and the farther you stand the smaller they will be. Do not stand too far away or too close. In the place where you stand make a perpendicular line, that is, a line that falls from your head to your feet. On this, place a mark three of these [proportional] braccia above the ground and see that this line does not pass the bottom line of your square, that is, the imagined window. Then with a thread, or rather a ruler, [draw a line] from this given term of three

braccia to each one of the three braccia marked on the window, that is, the [base] line of your window. Whether you use a string or a ruler make a point wherever it cuts the perpendicular line of your window. Do as I have said until you come to the other side of the square. Each time make the same mark where your thread cuts it. When you have marked all these parts, carry them to the opposite side of the window with your compasses. Even though one of these will seem wide to you and another narrow, pay no attention to it, because this is the way it should be. Then with your ruler draw a straight line from each of these points to the other you have marked.

Then place a string or ruler from the point that you have put on this [centric] line, whether it is above or anywhere alse, to the lines at the bottom of the square. Draw a line to each of these from this point, for these are an analogy to sight. These lines are the rays of your eyes, that is the aforementioned visual rays. You will see this plane all full of parallels, that is little squares of one braccio each. Even though some seem smaller yo you than others and although they do not seem to be square, nevertheless they are all equal and all squares of the same kind, as you will presently see. I think you have understood up to here how a plane is made [Fig. fol. 177v].

I have understood it, but I should like to see you make one. Tell me why these squares do not come out as squares.

It is because you see these things on a plane. If you saw them directly, they would appear to be squares to you. To prove that this is so, look at the pavement where square pieces of wood have been spread out, or better look at a ceiling from below. All the beams are equidistant from each other. To the sigtht, they seem to be more or and less. The closer they are to you the more equal they seem to be, and the farther away from you the more they seem to be close together that one is on top of the other and they all seem to be one.

If you wish to coinsider this more closely, take a mirror and look at them in it. You will clearly see that this is so. If they are exactly opposite your eye, they will only appear equal. I think that Pippo di Ser Brunellesco, The Florentine, discovered the method of making this plane in this way. It was certainly a subtle and beautiful thing to discover [how to do it] by rule from what the mirror shows you. Even so, if you consider it carefully, you can see by your eye this change and diminution.

Then measure whatever you put in this square with the same braccia on the line, where they are located, whether they be figures, animals, buildings, columns, or whatever you wish to do. Some will be smaller than others for the above named reason. If you look at a group of columns in a line, it will seem to you that the last ones are behind each other and one will seem smaller than the other. This happens for the reason stated above.

If you wish to erect a building, do it in the same way with your compasses. Determine how high and how wide you want to make it. With the compasses opened as wide as as one of these squares, make a perpendicular mark on one of the corners of the building and another in the same way on the other corner as wide as you wish the facade to be. For the side facade, see how much it will be at the nearer corner. Draw a perpendicular line from this parallel and stop your line. Erect another line at the farther corner. Then see how many [proportional] braccia there are in its height. This second [perpendicular] line will be as high as the first two lines even though it seems lower and shorter to you. This is because these braccia are smaller to the sight than the ones in front; in truth they are all the same size. It is the same with the lines of the building. Draw a line from the top as you have done on the bottom and join these lines together. These will be drawn with a string from the centric point, which has been mentioned before. Thus you will see all the parts measured [out]. Then if you wish to make doors, windows, or stairs, everything should be drawn to this point, because, as you have understood, the centric point is your eye, on which everything should rest just as the crossbowman always takes his aim on a fixed and given point.

If you should desire to portray something in an easier way, take a mirror and hold it in front of the thing you want to do. Look in it and you will see the outlines of the thing more easily. Whatever is closer or farther will appear foreshortened to you. Truly I think that Pippo di Ser Brunellesco discovered perspective in this way. It was not used by the ancients, for even though their intellects were very subtle and sharp, still they never used or understood perspective. Even though they exercized good judgment in their works, they did not locate things on the plane in this way and with these rules.

You can say that it is false, for it shows you a thing that is not. This is true; nevertheless it is true in drawing, for drawing itself is not true but a demonstration of the thing you [are] drawing or what you wish to show. Therefore, it is true and perfect for this, and without it the art of paiting or of the sculpture cannot be done well. You can also say, *You have praised so highly to me the ancient painters, Giotto and many others who did not use the measures, foreshortening, or all the things they should have. However, they were good masters and did beautiful and noble works.* You speak the truth, but if they had understood and used these ways, modes and measures, they would have been better. To prove that this is so, look at their buildings, for sometimes the figures are almost as large as the houses. Many times they also show the above and below of a thing at the same time. You could perhaps say that they knew it but did not wish to use it in order to avoid taking pains. This is even less trouble, for when a man knows it, he can make everything to measure. You always have a guide for whatever you wish to do, you know where you have to locate things, and you cannot err. Thus I conclude and say to you that if you wish to be a good master of drawing, you need to understand and use it when you draw [p. 302 till 306 op. cit]

Annex II

After making an improvised device, we decided to build a less precarious and easier to handle model of the mirror with the view-finder plate. This was accomplished with the help of the workers in the model work-shop of the Faculty of Architecture and Urbanism of the University of São Paulo. In this new version, we endeavoured to make it in the simplest possible way, looking forward to its eventual reproduction. That is how, with the collaboration of Edgar Spilla (supervisor), Dorly Aparecido dos Santos —for the wooden pieces— and Celso Faustino Ramos, for the metallic parts, we built a first model, with the following characteristics: a wooden screen for the mirror, measuring 30 cm x 50 cm, 2,5 mm thick, with a back support, heavy enough to guarantee the mirror's stability (dislodging the gravity center to a point behind the wooden plate) and to reinforce attrition so that the mirror stays fixed when we draw upon it. In this way the mirror can be easily displaced over a normal drawing table. For the view-finder plate, which has a graduation in quarters of centimeter, we made a steering ruler with a fixing screw so that we can obtain whichever height we wish, and we fixed the steering ruler in a brace easily adapted to the table.

Now, together with some post graduate colleagues we are studying some graphic exercises that may transmit the fundamental constructions of perspective. We think of using some acrilic transparent plates to study lines in space. The glass mirror will be substituted by very fine films of plastic and aluminum in order to lessen or eliminate the double image effect due to refraction (perceptible in glass). This last providence will enable us to vary the mirror angle in relation to the observer and add on some anamorphic exercises which shall give us the guide lines necessary to transfer perspective teaching by means of optics (and afterwards by means of geometric considerations) to graduation courses. Our goal, though, is to reach high-school. It is obvious that studies thus oriented cannot dispense with considerations on the artistic and cultural environment where perspective discovery was made.

The XXeth Century critics have tried to *save* the *vanguardist Art*, specially the *school of Paris* which apparently abandonned all intentions of perspective similitude, attempting, at least from the technical point of view, to reitroduce those scholastic conditions that allowed the appearance of that remarkable group of artists.

In truth, perspective never was an essential need of artistic expression. This fact though vaguely, was always known by critics as well as perfectly understood by masters, as we have sketched in the begining of this essay. The academic community's reaction to the presentation of Altamira paintings is an illustrative example of our affirmations in relation to critics. The autenticity of those paintings was not aknowledged until other pictures communicated, later on, in the XXeth century. Also, when Marquis Marcelino de Santuola, surprised by his five years old daughter's discovery of the wall paintings,in 1879, hastened to communicate his discovery to contemporary scientists, they received the news with utmost reticence and suspicion of fraud. We must

consider that, the good quality of the paintings was never doubted even if the researcher's honorability was. On the contrary, it was the paintings excellence that aroused the lack of trust, and there were those who suggested that the honest aristocrat would have paid a contemporary painter for the making of the so called forgeries.

Nowadays we reckon that Altamira wall paintings may have been produced in an era between 80.000 and 15.000 years ago (to us in this case, is more or less the same that they have been painted 80.000 or 15.000 years ago, because they are farther from florentine pictures, than we are). Nevertheless those parietal pictures are not an incipient and spontaneous try. Obermaier, the scholar, collected hundreds of little stone plates where we can identify *mode* of paintings afterwards produced in great dimensions in the walls of caverns, showing that they were accomplished after a long and meticulous training. Certain conventions used by those franco-cantabrian painters, are used still nowadays, apparently without interruption. It does not seem sensible, therefore, to imagine that painting has progressed from spontaneous efforts to attain its final completion aided by perspective. This proposition could tempt some inteligent minds in the last centuries, when it was believed that mankind was some thousands of years old, but it becomes ridiculous when we think that drawing and painting have been exercised for hundreds of thousands years.

Then, if perspective is not a decisive and necessary stage in evolution of art, what is its meaning for the ensemble of cultural activities? It seems to me that we may understand perspective, first of all, as a specific problem of italian painters and architects, beginning in the XIIIth century, in a situation that was unique and never to be repeated. In that sense, there is nothing better than the very testimony of one of those artists to enlighten us on their purposes. One of the most clear minded artist of his time, Piero della Fracesca, begins his treatise *Prospectiva Pingendi* with the following words:

"painting has in itself Three principal parts which we say that are drawing, measuring and colouring.

We understand drawing as the profiles and contours that things contain.

Measuring we say that are those profiles and contours proportionally put in their own right places.

As for colouring we understand that is to use colours as they appear in things, bright or dark according to the light that changes them. Of these three parts, I only intend to deal with measuring which we call perspective".

So, based in Piero, we may state that perpective is not really referred to drawing but to metric relations of objects.

This was the foundation for the new science that was being outlined and that found its counterpart, in a new precision which was present in all acts of dayly life: in commercial writings, in the new graphic references of sailing directions, for instance. The portuguese admiral Dom João de Castro, almost fifty years after Piero, in his *Tratado da Sphaera*, affirms:

"This is the true and perfect Geography, which consists chiefly in signalling the lands by the correspondence that each one has with heaven, with its very width and length; and in this way we can put the whole world and whichever part of it, be Province, Reign or Country, in an abridged chart, all with the utmost certitude. And the lands and islands that are newly discovered, though they may be many thousands of miles spread out in this sea Ocean, we can put them down in charts [maps] in their correct place and we can look for them again and find them without missing a single point in their right position"[op. cit. p. 95].

This new science is opposed to the allegoric knowledge characteristic of feudal structure and is more suitable to common men, salesmen, seamen (by the way, urban people), artisans, all of them interested in controlling and directing facts by means of rational knowledge. As D. João de Castro says:

"All error and imagination and sight lay in not understanding the way in which heavy objects fall perpendicularly - all men are wrong when they think that objects fall along equidistant lines, not seeing that this is false because the more the objects fall, the more they get together. And eyesight may forgive us if we point out this error, but it must confess its blindness on that subject, for all its sharpness, and here sense must obey to knowledge. To let sense lead us is beha-ving blindly, because we know for sure that, but for knowledge, we would be misled by sense in many ways.

Based only on the senses, all of us would think that the sun is more or less the size of a cart wheel, and stars like oranges, which would be a grave mistake for understanding [knowledge] has proved that the sun and many stars are bigger than the whole earth [...]" [op. cit. p. 35 and 3].

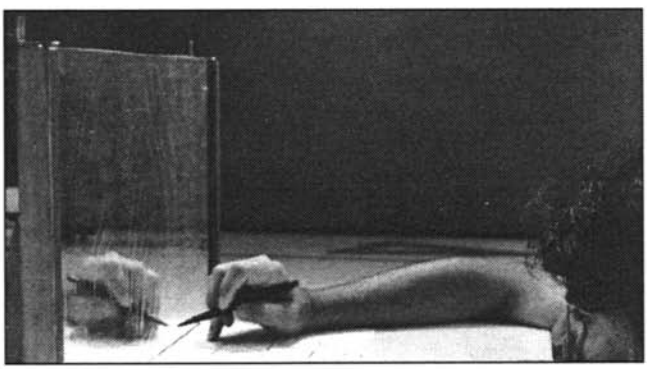
We do not think it to be abusive to approximate the portuguese navigator's quotations from those of Brunelleschi's —the florentine architect and goldsmith— registered as to have answered the court poet Giovanni Gherardi di Prato. Both were men interested in the new knowledge, both developed precise drawing studies: it was not for them just to look passively and reproduce more or less faithfully whichever view or landscape seen through a window. Their drawings were at the same time a *construction* and an investigation of reality. All the details that those artists have left in their sketch-books may be adjusted to what will be called *composition*. In fact, their landscapes always were compositions, never copies from the direct reality. The constant reivindication of Leonardo da Vinci, that painting was a science, which was generally interpreted as an impropriety, wins its very

significance: from Brunelleschi to Leonardo —almost during a hundred years, science progresses by means of those artist's hands and brains and navigator's travels— not in the forum of the universities. In other words, in this moment through perspective, science and art are one and only reality.

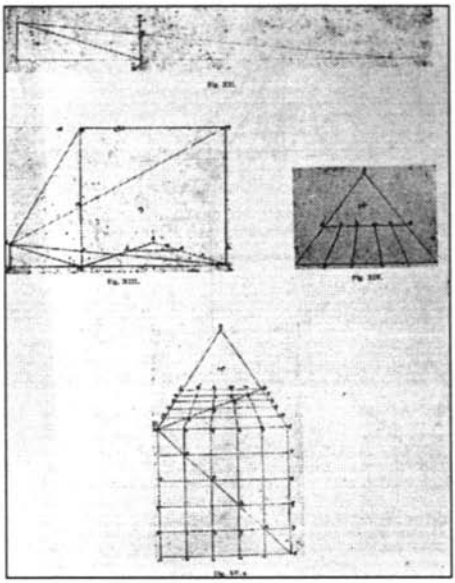
Perspective teaching by means of mirror reflections retrieves to school level this condition vaguely discerned by many critics, though perfectly absorbed by some brilliant artists in the last three centuries.

Our intention in making this a public problem, nevertheless, is to hope that it makes other teachers interested in it and that they bring forth their contributions and their own experiments, so that we can reach our objective of a creative education towards scientific and artistic level.

The photographs were made by Eduardo Castanho. Our special aknowledgment to Luis A. Valandro Keating and Domingos Pascale who redesigned respectively figures 1 and 7. Nazareth C. Cardoso made the typewriting.



Annex II photo I. *Use of the instrument*



Annex II photo II. *Objective lense substitutes the view-finder hole. The same verification made for the fig. 1a may be made upon the photography. Perspective (that is geometric construction of an image obtained from plane mirrors) as Descartes suggests in his Dioptrique, may be used as an ideologic basic for the studies of images built in eliptic and hyperbolic lenses.*

Annex III

Mathematical deduction of the perspective from the laws of modern optics.

In our previous researches, we demonstrated that the Renaissance perspective could be discovered empirically with plane mirrors. And according with Brunelleschi's contemporaries, this discovery was made by him.

We discussed also the contribution of Leone B. Alberti, and pointed out that he simplified the discovery of Brunelleschi, developing a geometrical method of construction and, most important, described his method in a book, which broke with the traditional behaviour of concealing their knowledge or their improvements within the interior of the Guilds.

But his method, being a simplification of the discovery of Brunelleschi, was at the same time a dilution of the scientific basis where the method was founded.

We started, to make these affirmations from a hypothesis that the *office method*, or *vanishing points method* preceeded Alberti's method, and with a very simple device we proved that we could deduce empirically the vanishing points perspective from the mirror's images.

But as this method was described and published only more than a century after Alberti's method, without any theoretical justification, our tradition consecrated the perspective by the distance points just as a practical device.

In this paper, we present the perspective construction based only on the laws of optics already described from the 17th century and available to build, even today, optical instruments.

With this in mind we can say:

The light ray can be seen as a straight line. The incident ray over a surface, the normal on this surface and the reflected ray are in the same plane.

The incident ray form with the normal, an angle that is equal to the angle formed by the normal and the reflected ray.

In a plane mirror the virtual image P' of a point P is in the normal to the surface passing in P, and its distance from the plane of the mirror is equal to the distance of the point P to the same plane.

Under these conditions, we assume a segment PQ of a vertical straight line at a said distance from a plane mirror, also vertical [figure 1], and we fix the observer's eye at the point P.

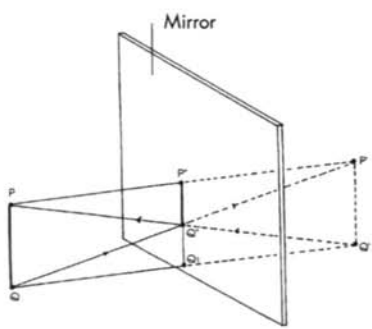


Figure 1

The virtual images P' and Q' of the points P and Q, are at the same distance from the plane mirror as PQ.

But the image in the mirror P"Q" is in the same plane of PQP'Q', but its dimension of one half of PQ, and this proportion is independent of the distance of PQ to the mirror [figure 2].

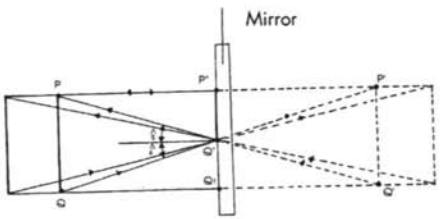


Figure 2

Now we take a point L in the QQ' ray. The virtual image L' is found on the same ray, and the image on the mirror L" is in the prolongation of the straight line P"Q" [fig. 3 and 4].

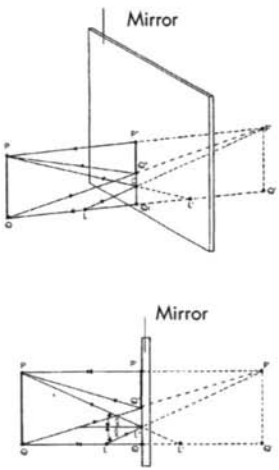


Figure 3 and 4

Now we consider a plane normal to PQP'Q' through line QQ', which intersects the plane of the mirror with a horizontal plane passing through point Q_1. Through the points Q and L, of this plane, we trace two lines, QQ_1' and LL_i' that have an angle of 45 degrees with the line QQ' [figure 5].

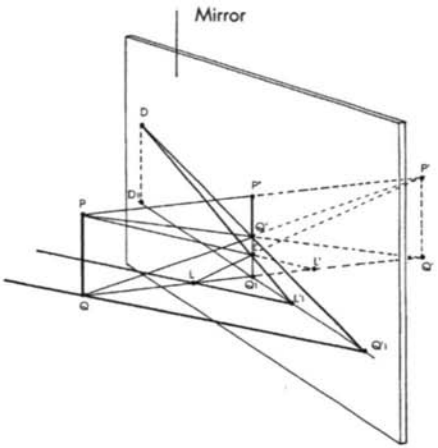


Figure 5

We call these lines *diagonals*. The image in the mirror of the line QQ_1' is Q_1'Q" and LL_1' is L_1'L". Indeed Q_1' and L_1' are simultaneously points of the lines in the said horizontal plane, and its images. The points Q" and L" are, by the previous construction, the images of the points Q and L.

The lines L_1'L" and Q_1'Q" in its prolongation must reach a common point D, because Q"L"L_1'Q_1' is identical to Q"QLL" and Q"L"P is identical to Q"L"D.

We can say that DP" is equal to P"P, because the triangles Q"Q_1Q_1'and Q"P"D have one equal side (Q"Q_1 ∫ Q"P") and two adjacent equal angles (Q"Q_1Q_1'∫ Q"Q_1Q).

This means that DD_1 ∫ P"Q_1 ∫ PQ. In other words DP" defines a horizontal line. It is easy to show that D has a symmetric point D' in relation to P". These two points received, traditionally the names of *distance points*, because they reproduce, in the plane of the mirror the distance of the observer's eye to the mirror. The straight lines at 45∞, also called *diagonals*, receive this name from the lines of the square, and it is a historical fact that the european painters, especially italians, who attempted to locate squares, or lattices in perspective with an empirical rule that was criticized by Alberti in his book *De Pictura.*

If we take a point T, symmetric to Q, in relation to P in the same vertical, we can verify that the diagonals traced in an horizontal plane passing through T, also have their mirror images meeting points D and D' [figure 6].

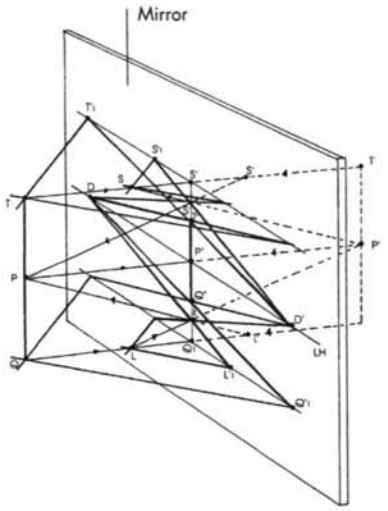


Figure 6

The horizontal line DP"D' is the geometric site of all horizontals and with the inclination relative to the plane of the mirror.

In these conditions, it is easy to prove that the perpendiculars to the mirror, cross in the point P" [in figure 7, the straight line R_1'P" is the intersection of the plane PP'ZZ' with the plane of the mirror].

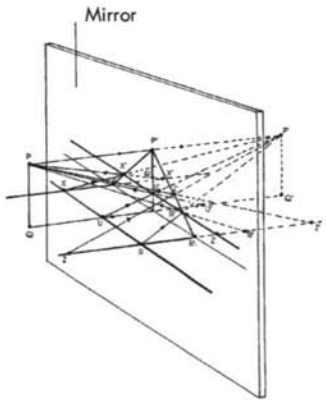


Figure 7

In brief, for these constructions, the fundamental lines are a vertical and a horizontal line, both passing through the observer's eye, reduced to a point.

With this demonstration, the conviction of the perspective practiced by the florentine artists as Brunelleschi and Paolo Uccello, was a necessary step between medieval and modern optics, founded by Descartes and Huygens.

The italian painters did not discover the perspective by chance, but through a systematic research supported by the work of their scientific contemporaries, experts in traditional optics. But we can say, with professor Santillana, that Brunelleschi was the most powerful scientific mind of his time, because, as far as we know, he introduced a method for the construction of the mirror's image, which established a precise relation between the image and the object represented in the mirror, contributing in this way to the rise of modern science.

Nevertheless, this paper does not intend to do historical justice, or a correction in history of art or science, but can be an improvement for a more rational learning of perspective and drawing.

BIBLIOGRAPHY

ALBERTI, Leone Battista (1989) *Da pintura.* Tradução de Antonio da Silveira Mendonça. Campinas, E. Unicamp.

——— (1956) *On Painting.* Translated with introduction and notes by John R. Spencer. London, Routledge and Kegan Paul.

ANTAL, Frederick (1947) *Florentine Painting and its Social Background.* London, Kegan Paul.

ARVELINO, Antonio Piero (d. il Filarete) (1972) *Tratato di Architettura.* Testo a cura di Anna Maria Finoli e Liliana Grassi. Introduzione e note di Liliana Grassi. Milano, Il Polifilo.

——— (1965) *Filarete's Treatise on Architecture.* Translated with an introduction and notes by John R. Spencer. New Haven, U.P.

CASTRO, D. João (1940) *Tratado da Sphaera.* Prefacio e notas por A. Fontoura da Costa. Lisboa, Agência Geral das Colonias.

DELLA FRANCESCA, Piero (1942) *De Prospectiva Pingendi.* Edizione critica a cura di G. Nico Fasola. Firenze, Sansoni.

DESCARTES, Rene (1982) *La Dioptrique.* Oeuvres de Descartes, Publiës par Charles Adam et Paul Tannery. Paris, J. Vrin, vol. VI.

FRANCASTEL, Pierre (1970) *Etudes de Sociologie de l'art.* Paris, Denoel.

GALILEI, Galileu (1930) "Sidereus Nuncius". In: *Le Opre di Galileu Galilei.* Firenze, G. Barbara, vol. II.

——— (1987) *A mensagem das estrelas.* Tradução, introdução e notas de Carlos Z. Camenietzki. Revisão critica de Adriano G. Cury. Rio de Janeiro, MAST.

GHILBERI, Lorenzo (1947) *I Commentarii.* A cura di Ottavio Morisani. Napoli, Riccardo Ricciardi.

HUYGHENS, Christian (1986) "Tratado sobre a luz". Tradução de Roberto A. Martins revista por Lilian A.P. Martins. In: *Cadernos de História e Filosofia da Ciência,* Suplemento 4, 1-99. Campinas, Unicamp.

KATINSKY, Julio Roberto (outubro 1982) "Um experimento com a ciência e tecnologia dos primeiros anos do Quatrocentos em Florença". In: *Ciência e Cultura 34(10).* Sao Paulo, SBPC.

MANETTI, Antonio (1976) *Vita di Filippo Brunelleschi.* Edizione critica di Domenico de Robertis, intróduzone e note di Giuliano Tanturli. Milano, Il Porfilo.

——— (1970) *The Life of Brunelleschi.* Introduction, notes and critical edition by Howard Saalman. The Pennsylvania, State University Press.

MARINGER, Johanes J. y BANDI, Hans Geor (1952) (en continuación de un proyecto de Hugo Obermaier). *Arte Pre-historico.* Basilea, E. Holbein.

MOTTA, Flavio (1963) *Apontamentos de História da Arte: O milagre da fonte.* São Paulo, FAU.

PARRONCHI, Alessandro (1964) *Studi Sulla dolce Prospettiva.* Milano, Aldo Martello.

PRAGER, Frank D. and SCAGLIA, Gustina (1970) *Brunelleschi - Studies of his technology and inventions.* Cambridge M., M.I.T. Press.

SANTILLANA, Giorgio de (1981) *O papel da arte no renascimento cientifico.* Tradução de Eunice R. Ribeiro Costa, revisão tecnica de Sylvia Ficher e introdução de Julio R. Katinsky. São Paulo, FAU.

VASARI, Giorgio (1822) *Opere di Giorgio Vasari, pittore e architetto aretino.* Firenze presso, S. Audin e Co.

——— (1957) *Vidas de artistas ilustres.* Traducción del italiano por Agustín Blánquez et al. Barcelona, Iberia.

VENTURI, Lionello (1947) *La Pittura-Come si guarda un quadro.* Roma caprioti.

VITRUVIO, Marco Lucio (1955) *Los Diez Libros de Arquitectura.* Traducción, prólogo y notas por Agustín Blánquez. Barcelona, Iberia