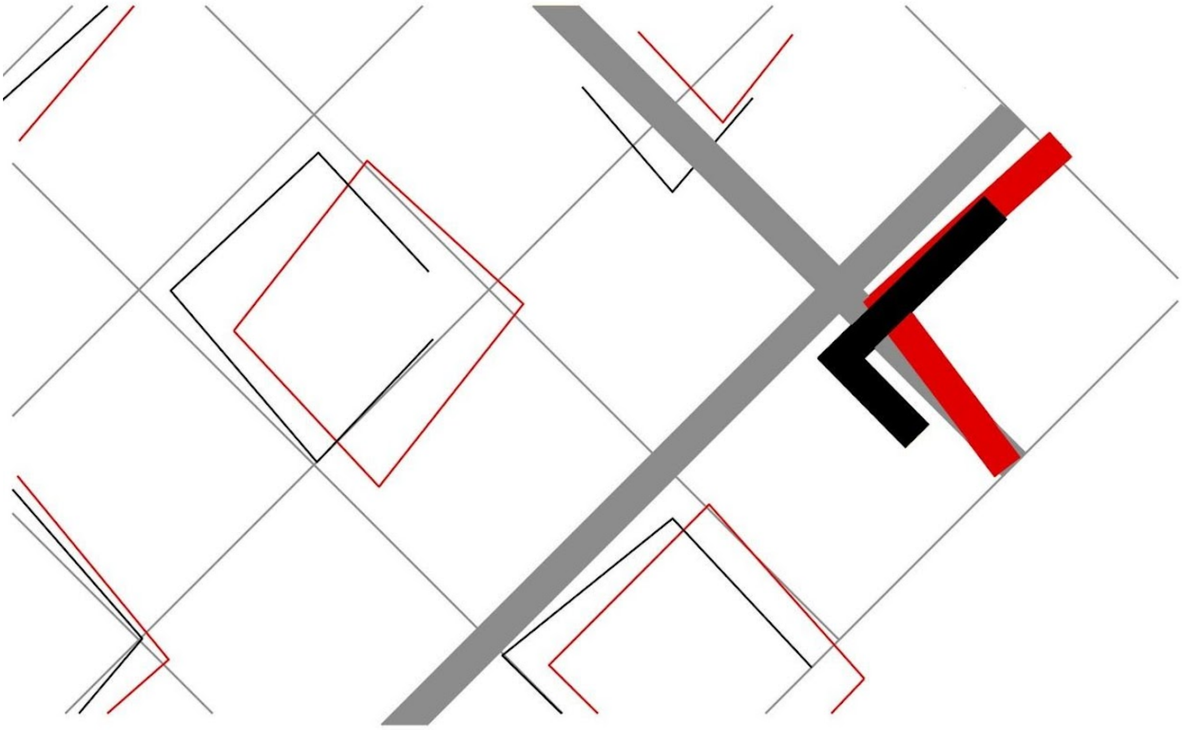
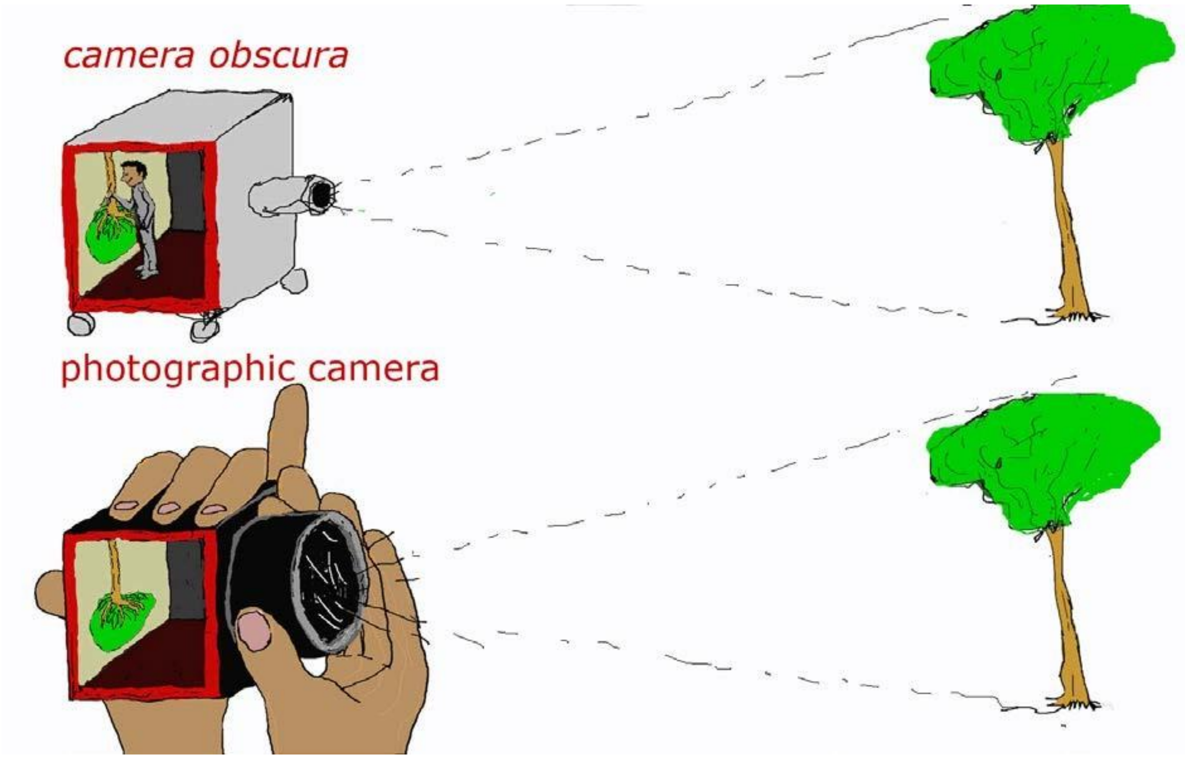
01 CADoP Papers
Computer Aided
Deconstruction of Perspectives

How and for what used Vermeer the *camera obscura*.



Miguel Usandizaga


camera obscura
photographic camera

How and for what used Vermeer the *camera obscura*. On the perspective in *The Music Lesson*.

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Text and drawings by the author.

Abstract

Perspective deconstruction (traditionally called “perspective restitution”) is the inverse procedure to the geometrical construction of perspective. This graphical analysis offers promising possibilities if done with a computer and two-dimensional CAD software. Here we use this technique to analyze the perspective in a painting by Johannes Vermeer, *The Music Lesson*. We compare two different versions of this perspective: the original one and that of the recreation painted by Tim Jenison and presented in the film *Tim’s Vermeer*. We have especially considered the perspective of the flooring, a grid that requires a lot of precision to draw it accurately. Our conclusion is that Vermeer could not geometrically construct this perspective with the instruments at his disposal in the seventeenth century. Therefore, he had to draw it with the only alternative system known at that time; tracing the image projected in the interior of a *camera obscura*. This research offers geometrical evidence that Vermeer used a *camera obscura* to draw the perspectives in his paintings.

Credits

Lo que haya que poner y además:

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How and for what used Vermeer the *camera obscura*.
On the perspective in *The Music Lesson*.

Attempting to reproduce one of the works of Vermeer… without knowing how to paint. This is Tim Jenison's unusual endeavour, presented in the film Tim's Vermeer (2013). Although he received devastating criticism (Jones, 2014; Pulver, 2014; Oredsson, 2017), his wild idea is useful. It allows us to compare two distinct perspectives of the same painting.

Let us concentrate on the perspective of the flooring; a checkerboard, a geometrical drawing solved with excellent accuracy by both Vermeer and Jenison. Nevertheless, the two floors show a difference, which is doubtlessly the most evident difference between both paintings. In the lower left corner of the painting, we see in Vermeer (**Fig. 6V**) the diagonal line between a light and a dark tile; in Jenison, instead, the same corner shows the middle of a dark tile (**Fig. 6J**). Furthermore, there are three light tiles in the first row in Vermeer, and only two in Jenison. Why?

One answer could be that both floors were different. This is not true. If we look more closely at the dihedron formed by the flooring and the left wall, we can see that both are identical; in the most distant corner there is a quarter of a light tile, and along the dihedron there are the same number of light tiles in both cases. In Jenison, we see a bigger part of the closest tile than in Vermeer, and a slightly bigger part of the closest window.

(We can assume that the tiles are square because this is the norm; tiling with irregular pieces would be crazy. The tiles, which, in the well-founded assumption of Philip Steadman (2001), are painted on a base of ceramic tiles, are often rotated 45 degrees to hide imperfections in the dimensions of the pieces and their correction with the thickness of the joints.)

If both floors are the same, but we see them different in perspective, it has to be because the viewpoint is in a different position. A perspective is the result of a relationship between a reality and a point of view from which one looks at it or from which it is geometrically projected.

The procedure of Computer Aided Deconstruction of Perspectives (CADoP) will allow us to locate in plan and section the viewpoints of these perspectives. However, beforehand, let us recall some fundamental concepts on the geometrical construction of perspectives.

Before the advent of Computer Aided Design (CAD) and its development in the last third of the twentieth century, only two methods were known for drawing perspectives: following visual perception (**Fig. 1**) or constructing them geometrically from floor plans and cross sections (**Fig. 3**).

The drawings resulting from one or the other of these systems may be identical, which led Erwin Panofski (1927) to state, regarding the perspective projection, "it does not matter whether this projection is determined by an immediate sensory impression or by a more or less 'correct' geometrical construction."

The most accurate perspectives obtained directly from visual perception are those traced over the projection of a *camera obscura,* or those produced through a chemical process without human intervention in a photographic camera, the descendant of the *camera obscura* (**Fig. 2**).

Technology has opened up new possibilities; digital cameras can take perspectives from vision, and computers can generate geometrical construction of perspectives with the capacity for producing images in perspective from electronic three-dimensional models. The problem with these models is, as J. V. Field (2005) explains, that CAD 3D technique used in perspective restitution "makes far too many automatic assumptions for the results to be helpful in assessing paintings."

CADoP offers a new method: deconstructing perspectives with two-dimensional CAD, using only traditional drawing techniques. In other words, making ruler and compass geometry with absolute accuracy, which was not possible with paper and pencil for two reasons; because of the limitation of the workspace in paper, and because of the unavoidable inaccuracy in pencil drawing. It is an anachronistic use of CAD: as if the computer screen were just an unlimited surface, on which we could draw with absolute accuracy.

Tim Jenison drew the perspective for his version of *The Music Lesson* using CAD. As he explains in his film, he built a life-size replica of the room in which Vermeer had painted the painting. For this, he constructed a model in three-dimensional CAD using the software *Lightwave 3D*, developed by NewTek, a firm he had founded in 1985 with Paul Montgomery. He obtained his perspective from this electronic model.

Again, we will not assess the inconsistencies of Jenison's work. What we are interested in is knowing why he used the CAD to build the perspective, if the general purpose of his work was to demonstrate that to paint like Vermeer, using the machine he had built was enough.

The answer is clear. Jenison's machine, a simple mirror (Gfish, s.d.), is a very elementary variant of the *camera lucida* patented by William Hyde Wollaston in 1806, and much earlier described by Johannes Kepler. These machines do not project images, as the camera obscura does, but allow you to see superposed (or almost superposed in the case of Jenison) both the model and its drawn representation. Therefore, they do not allow one to

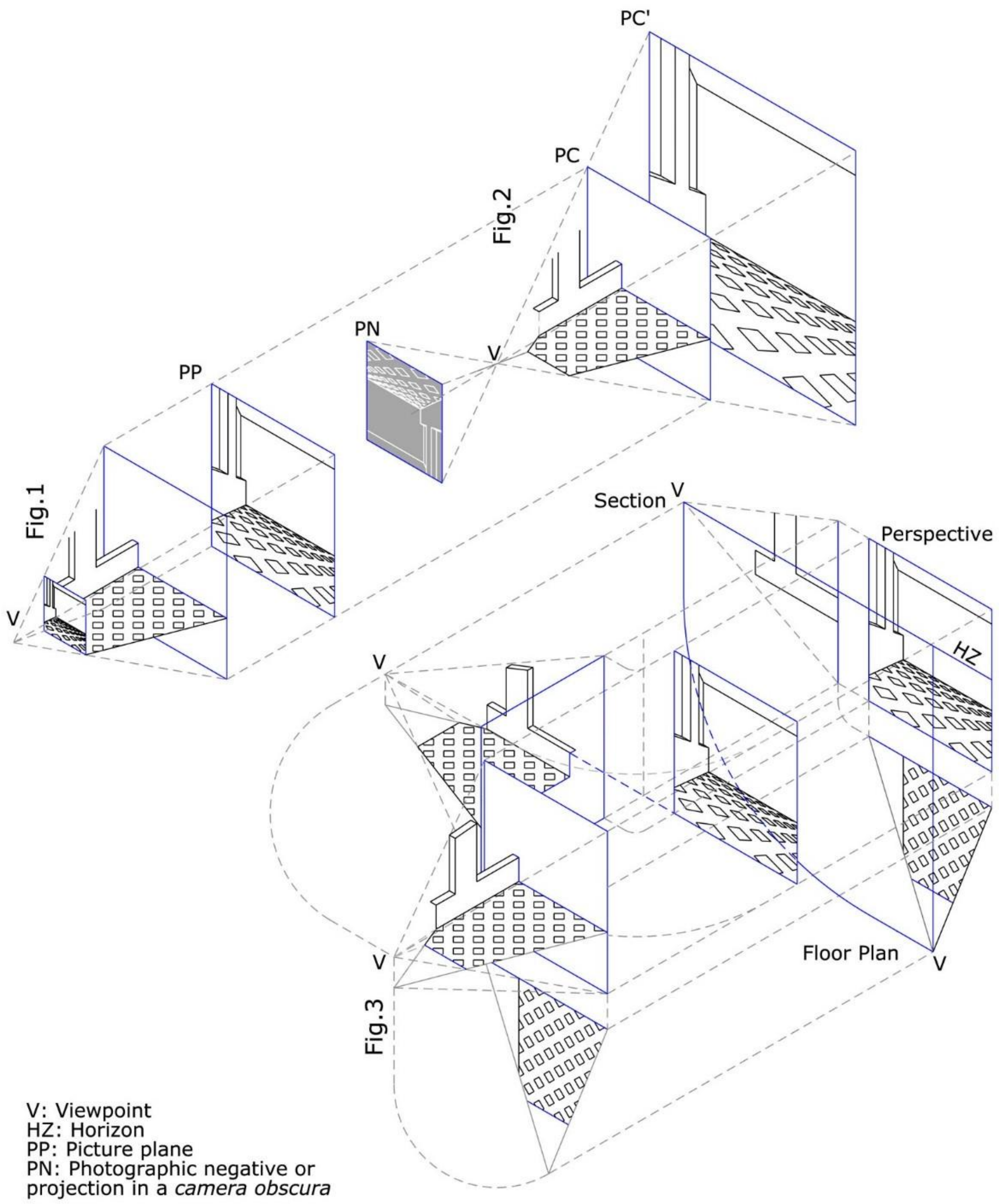


Fig. 1 A perspective drawn following visual perception. The treatise on geometry by Albrecht Dürer proposed, in some very well known engraving (1st. edition 1525, 2d. edition 1538, after Dürer's death), solutions for the problem of the picture plane, which has to be both transparent (to see through it), and opaque (to paint on it). Fig. 1 to 3 are isometric projections.
Fig. 2 A perspective produced with a *camera obscura*, or with a photographic camera. The plane of the picture is not a reality, but a convention. It depends only on the size you wish to draw on or reproduce the perspective.
Fig. 3 Drawings of planes for the geometric construction of the perspective. Note that all perspectives obtained with any of these three methods are the same.

enlarge the drawing by enlarging the projection. In addition, they have a severely limited field of vision because they have to interpose between the eye of the user, and their drawing.

To do the whole painting, Jenison had to move his machine many times, which means changing the viewpoint many times. In addition, he needed a general base to fit all the images together. Otherwise, he would paint something similar to David Hockney's "joiners". This basic layout in perspective is what Jenison constructed with CAD.

Jenison did not know where the viewpoint was located in Vermeer's perspective and tried to locate it based on the field of vision, and supposing that Vermeer's perspective was "frontal". It is not surprising that he made this supposition. Philip Steadman (2001), for instance, analysed several perspectives by Vermeer in depth, among them that of *The Music Lesson*, and supposed that they were all frontal. Frontal perspectives – also called "one point perspectives" – are a singular exception among all perspectives. We will see why after revising some necessary basic concepts.

In perspective, vanishing points are all points where straight lines, being parallel in reality, appear to converge on the image plane. If these lines are horizontal like these in the floor we are analysing, their vanishing points are in the line of the horizon in the perspective. The horizon line ("HZ") is the line of the dihedron formed by the picture plane ("PP") on which the perspective is drawn and the plane of the horizon, the horizontal plane containing the viewpoint ("V") and the vanishing points for horizontal lines (**Fig. 4**).

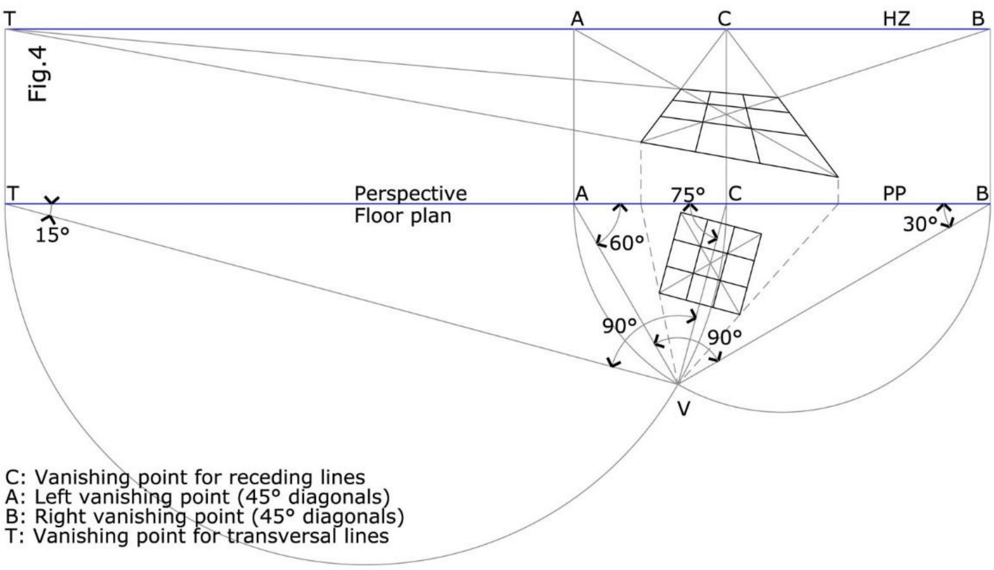


Fig. 4 Geometrical construction of any non-frontal perspective.

There are no one, two or three point perspectives; for every set of parallel lines we can see in a perspective, there is a corresponding vanishing point.

Two pairs of parallel lines that are perpendicular to each other delimit a square. It also contains two other lines that form a right angle between them and a 45 degree angle with those of the contour of the square; its diagonals, which even if they are not drawn, we see them. The painting by Daniel Vosmaer *A View of Delft through an Imaginary Loggia* (1663) illustrates perfectly how diagonals denounce a wrong perspective.

Contour and diagonal lines give, in the perspective of a square, four vanishing directions. Let us call "A" the vanishing point for left diagonals, "B" the one for right diagonals, "C" the one for receding lines, and "T" the one for transversal lines.

The triangles AVB and TVC are rectangular, with their right angles in V. According to Thales theorem, the right angles in V have to be in the semi circumferences with diameter AB and TC. Therefore, V has to be in the intersection of them (**Fig. 4**).

This is the general rule, with just one exception: frontal perspectives, characterized by three interrelated particularities:

a) In these perspectives, the vanishing point T is in infinity, so that the transversal lines are all parallel to the horizon line and to the picture plane.
b) The semi circumference TVC has an infinite diameter, it is a vertical line crossing the horizon in C and containing the viewpoint. The distances AC, CB and CV are all equal, the angles in A and B of the triangle AVB all measure 45 degrees.
c) The distances between the intersections of receding lines with any transversal line are constant (**Fig. 5**). This last characteristic allows us to take measurements in these perspectives, and also to increase or decrease their size proportionally.

These particularities make these exceptional kinds of perspectives much easier to construct geometrically than any non-frontal perspective. It is not necessary to take into account T, the most distant of the vanishing points. In any other perspective, this point must be located. Furthermore, the closer to the frontal the perspective is, the farther away this point is. This made constructing almost frontal perspectives with paper and pencil impossible. There was no paper, ruler nor drawing board with the necessary dimensions.

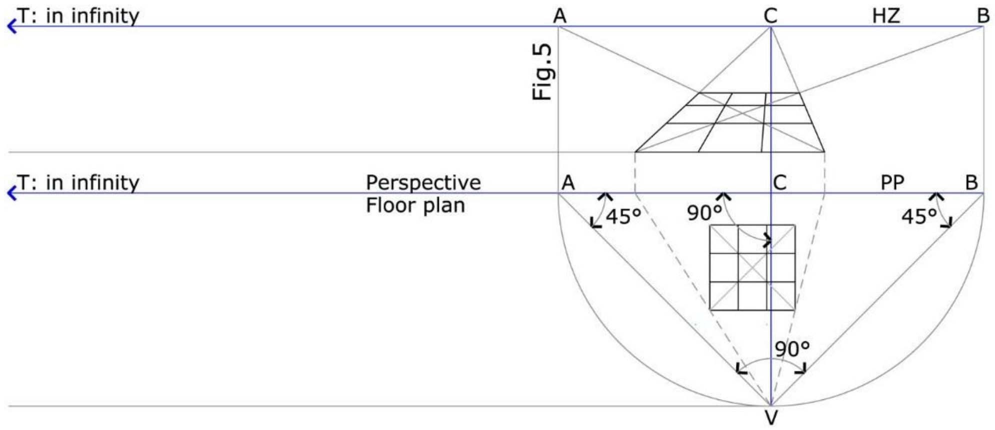


Fig. 5 Geometrical construction of a frontal perspective.

On the other hand, the necessary space for the geometrical construction of frontal perspectives can be limited to the distance AB, leaving point C point between A and B. Obviously, perspectives with 45-degree obliqueness have to be considered as frontal, just changing contour lines for diagonals.

These difficulties do not affect computers; they do not care at what distance a vanishing point is. We should remember that computers do not draw, they calculate. For increasing or reducing distances, they only have to move a decimal point.

The first perspectives produced with geometrically correct methods, constructed in Florence in the fifteenth century, were frontal. Brunelleschi already used the 45-degree diagonals vanishing points for the missing panel of the Florentine baptistery, a building with octagonal ground plan, considered the first correctly constructed perspective (Damisch, 1987). The methods for the construction of frontal perspectives developed immediately after. For instance, the method defined by Leon Battista Alberti, or the one used by Piero Della Francesca, which J.V. Field (2005) exhaustively studied.

The majority, if not all, deconstructions of perspective analysed frontal perspectives; a single example being, the historical paper by R. Wittkower and B.A.R. Carter "The perspective of Piero Della Francesca's Flagellation" (1953). This publication states that Piero used his own method for this painting, "working out perspective from plan and elevation".

It is also significant that most of the traditional vocabulary used in perspectives fits only with frontal perspectives. For instance, "principal point" (central vanishing point C, centred between A and B); “principal ray” (straight line connecting the viewpoint in ground plan with the principal point) and “distance points” (A and B vanishing points for 45-degree diagonals, at the same distance from the principal point).

Let us now consider the perspectives in *The Music Lesson*. We do know that Jenison constructed his perspective using CAD, despite the use of a computer not being essential to construct a frontal perspective, as Jenison believed *The Music Lesson* to be (**Fig. 6J**). What about Vermeer? As we will now see, Vermeer’s perspective for *The Music Lesson* is not a frontal perspective; it is almost frontal (**Fig. 6V**).

The vanishing point for transversal lines T is not in infinity, but almost 22 meters away from point C. It is physically impossible to construct this perspective geometrically without CAD. If something is certain, it is that Vermeer did not have a computer at his command. This poses the question we are trying to answer: How, with what instruments, could Vermeer draw this perspective?

The method of Computer Aided Deconstruction of Perspectives allows us to answer this question. We will leave the complete description of the CADoP process for another occasion, and concentrate on two steps of this process for which the use of CAD is essential:

The localization of the viewpoint and the point-by-point deconstruction of perspectives. Let us see:

a) Localization of the viewpoint.

The first advantage CAD offers for this analysis is in the infinite extension of the workspace. On the screen of a computer, it does not matter at all if a vanishing point is two, twenty, or two hundred meters away. With paper and pencil, on the other hand, the dimensions of the instruments and the surface of the material support for drawing dramatically limit the workspace.

Using CAD, we can locate the viewpoint of any perspective of a square grid without worrying for the distance at which the T vanishing point for transversal lines is located. We use the procedure already described (**Fig. 4** and **5**), and check that while the perspective in Jenison is frontal, with the T point at infinity (**Fig. 6J**) and consequently with horizontal transversal lines. On the other hand, the one in Vermeer is almost frontal (**Fig. 6V**), with the T point at 21.88m from C. To see the T point and check the vanishing of transversal lines, we have to print the drawing in a folder and on a very small scale. (Pages 20 to 24 reproduce this folder).

Vermeer could not construct this perspective geometrically, but neither could he achieve this accuracy in the vanishing point T without using an optical machine. It is worth noting that, while frontal perspectives are much easier to construct geometrically than the almost frontal ones, if we use a photographic camera or a *camera obscura* a frontal perspective is very difficult to obtain, as we have to ensure the exact parallelism between the projection plane in the *camera obscura* and the transversal lines.

It seems probable that Vermeer wanted to draw a frontal perspective, they were the norm at that time, but did not achieve it perfectly. The first transversal line of corners of light tiles of his painting falls clearly to the right, leaving the front corner of the light tile farthest to the right cut.

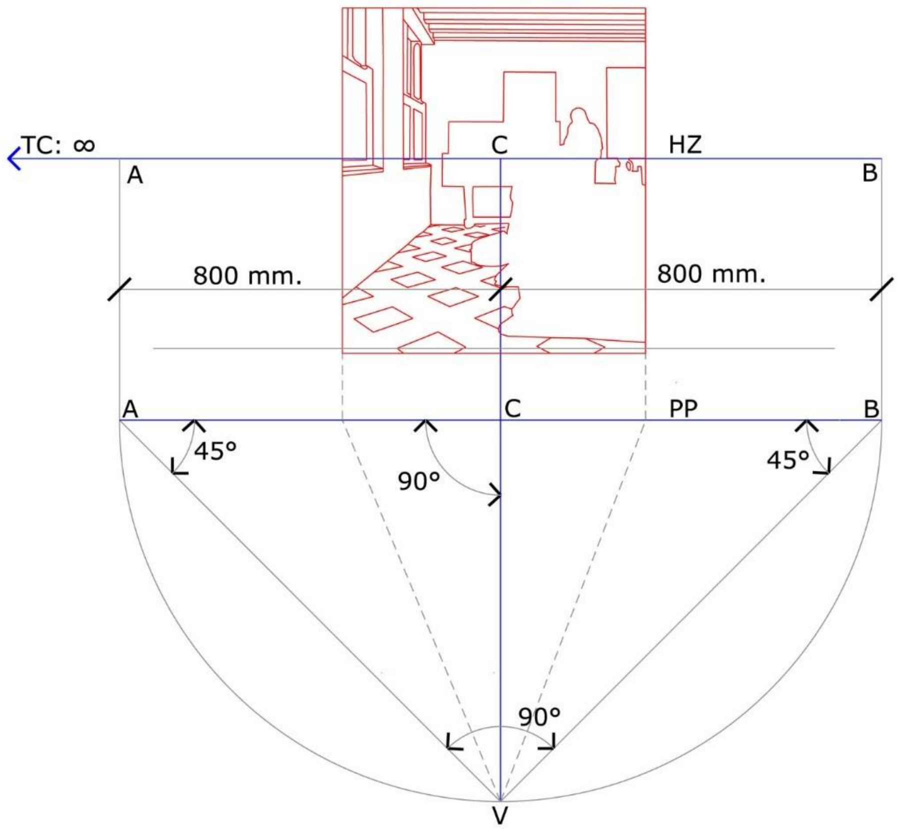


Fig. 6J (Jenison, red) Localization of the viewpoint.

Once the position of the point of view in both plan and elevation is fixed, we can begin the deconstruction of the perspective. That is, the situation in space, in its orthogonal projections of plan and section of the lines and points are drawn in perspective according to the dihedral system, as defined by Gaspard Monge.

b) Point-by-point deconstruction of perspectives.

The second advantage offered by CAD is its absolute accuracy. Traditionally, perspectives were deconstructed supposing that all lines and points in the drawing exactly coincided with a regular grid defined by the viewpoint and the vanishing points. Zooming in the computer screen is enough to notice that, in general, this was not the case; many points and lines deviated from this regular grid (**Fig. 8**, **9J**, **9V** and **10**). It is well worth remembering that painters paint with brushes, which are very imprecise instruments.

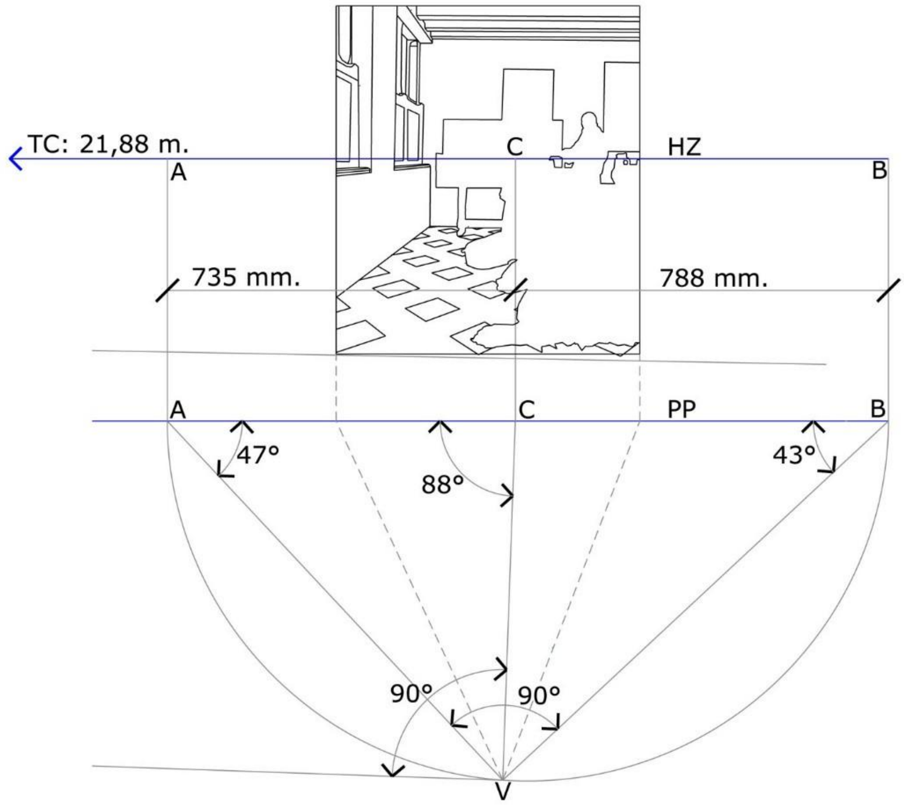


Fig. 6V (Vermeer, black, detail) Localization of the viewpoint. This drawing is a fragment. The complete image is printed in pages 20 to 24.

Note for figures **6**, **9** and **10:** we work on a tracing of reproductions of the painting to avoid copyright issues. We can do the same drawings directly on reproductions (See **Fig. 11**).

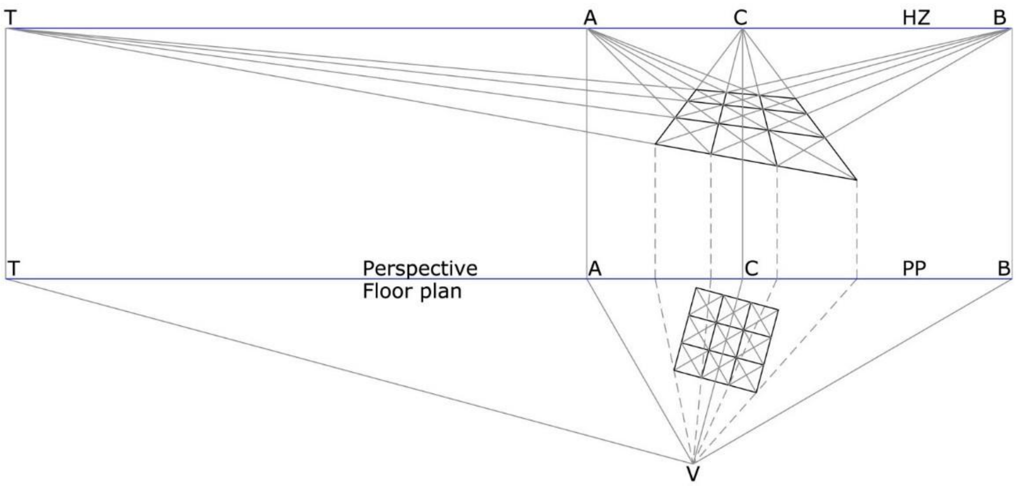


Fig. 7 Deconstruction of a perspective representing a regular square grid.

The other possible method for deconstructing perspectives – point-by-point deconstruction – does not use regular grids based on the vanishing points, but uses solely the situation of the picture plane and the viewpoint in ground plan and section to deconstruct any of the points we see in the perspective. With paper and pencil, the lack of accuracy and the accumulation of projection lines, which are impossible to suppress nor distinguish, made the use of this system impossible.

Finally, when we have finished both deconstructions; the regular grid of points and lines vanishing at specific points (**Fig. 7**) and the irregular one that finds us in plan and section any point we see in the perspective (which do not form a regular grid, but approximate it) (**Fig. 8**), we can superpose them (**Fig. 9J** and **9V**).

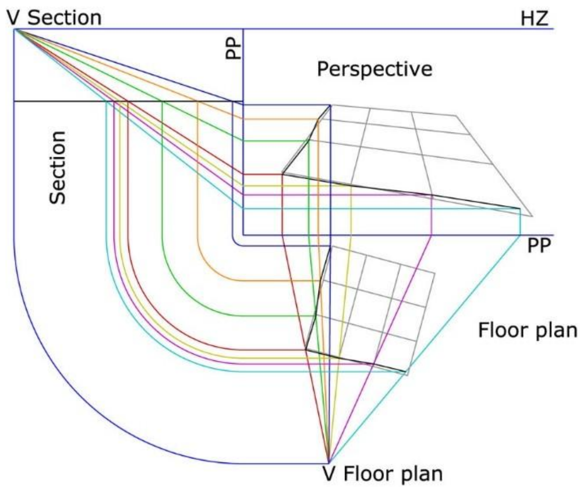
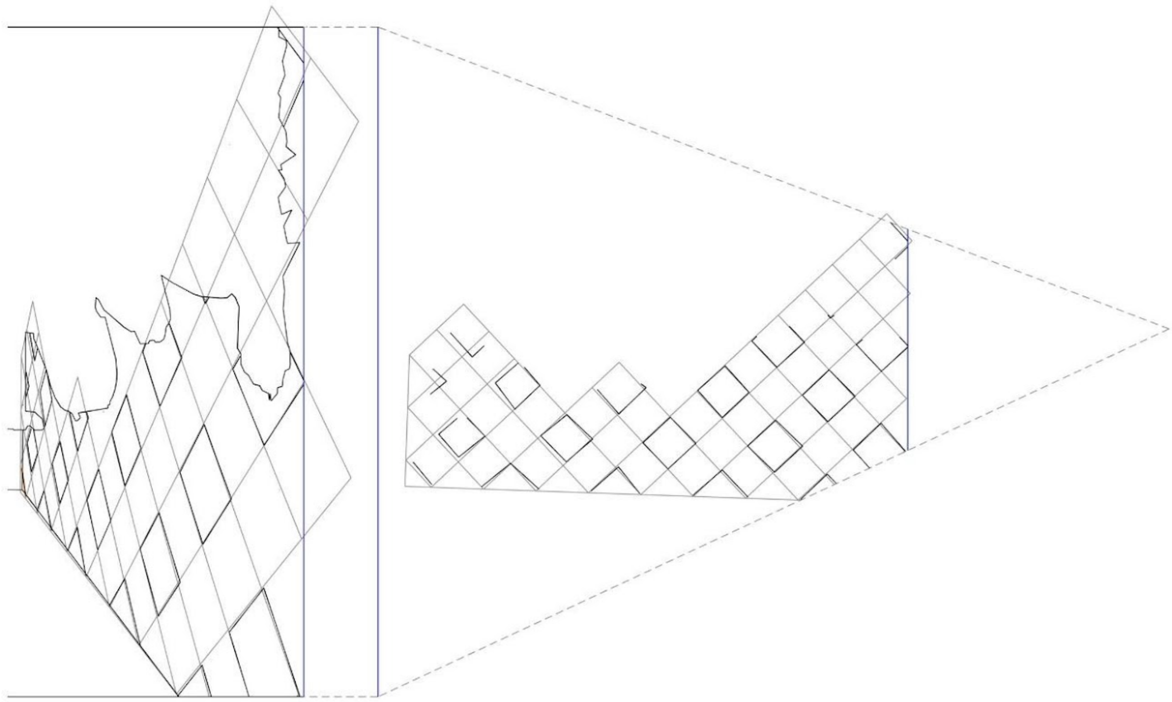


Fig. 8 Point-by-point deconstruction of a perspective.

In this case, we can also superpose the deconstructions of Jenison and Vermeer (**Fig. 10**) and check that, each one being consistent with their viewpoint, both represent the same square grid, the same floor, deviating from it in different directions. These differences, which are greater in the furthest part of the flooring, where the dimensions of the grid in perspective decrease to one third of those of the first row, are attributable to imprecisions of the painter, who uses a brush instead of a computer, and not to the construction of the perspective.



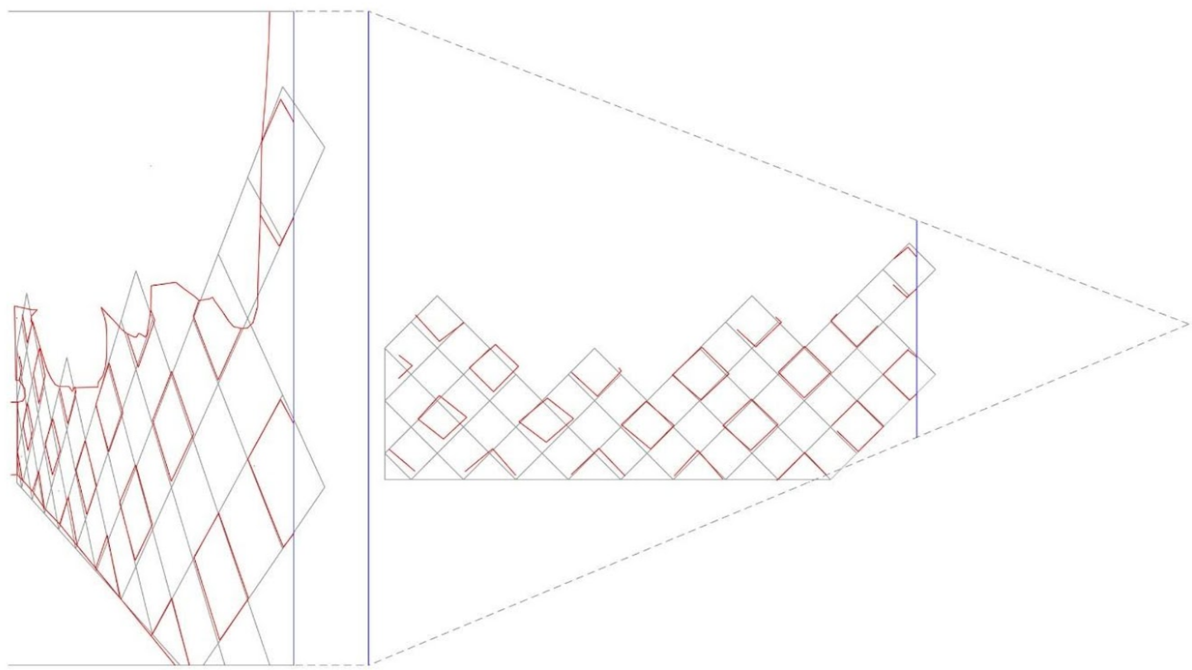


Fig. 9J Superposition of point-by-point deconstruction of Jenison over a regular grid.
Fig. 9V Superposition of point-by-point deconstruction of Vermeer over a regular grid.

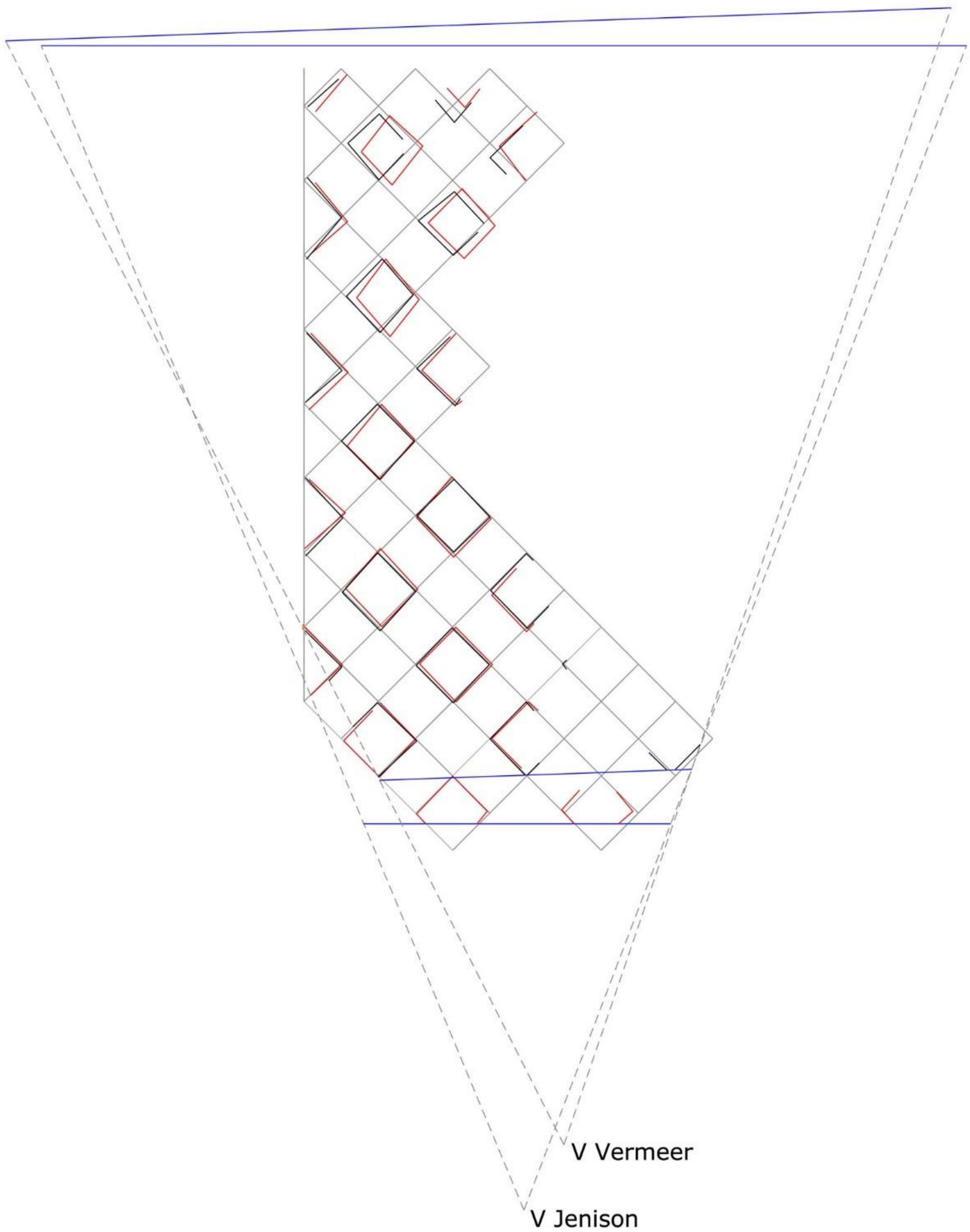


Fig. 10 Superposition of point-by-point deconstructions of Jenison (red) and Vermeer (black) over a single regular grid (gray).

Conclusion

Let us return to the question: disregarding geometrical construction (and, obviously, computers), how could Vermeer paint this perspective with an accuracy that equals or even overcomes Jenison's computer? With what kind of optical machine?

This question forms part of the discussion about the use or not, by ancient masters, and specifically Vermeer, of optical machines for painting. A discussion started in the nineteenth century, which the painter Jonathan Janson (2002) reviews in his website *Essential Vermeer*, and which was revived in 2001, when the painter David Hockney and the physicist Charles Falco presented the book *Secret Knowledge: Rediscovering the Lost Techniques of the Old Masters*. In the same year, architect Philip Steadman published *Vermeer's Camera Uncovering the Truth behind the Masterpieces*, a book that, clearly from its title, supports the thesis that Vermeer used a *camera obscura*.

Not all scholars accept this thesis, and argue reasonably about the lack of direct or documentary evidence that dissipates any doubt about the use by Vermeer of a *camera obscura* (Grosvenor, 2014; Snyder 2015). In the words of Jonathan Janson:

> "Why have scholars imagined that Vermeer used the *camera obscura* as an aid to his painting? There is, after all, no historical evidence to support this idea—the camera leaves no physical trace of its use—but only the visual evidence exhibited by the paintings themselves."

The author of this paper is not an art historian, but an example of an endangered species: an architect with knowledge of geometrical construction of perspectives and, even rarer, an ability to draw with a computer. The intention of this work is simply instrumental: offering to the historians a new procedure that is undoubtedly useful for their research: computer aided deconstruction of perspectives. Lacking the "physical trace" mentioned by Janson, CADoP allows the discovery of at least a "geometrical trace" of the use of a *camera obscura* for painting. Our thesis in this case is the following:

In order to draw the perspective in *The Music Lesson,* Vermeer had to use a *camera obscura*. Specifically, one of the booth type, great enough to allow the painter to enclose himself in its interior and trace the image projected in the rear wall. The opening of this camera had to be equipped with appropriate lenses to focus precisely the projected image.

The booth type *camera obscura* was the first known, and was probably discovered by chance, seeing that a hole in a wall of a darkened room projects on the opposite wall the inverted image of what is happening outside. The more recent box type camera obscura, such as that of Canaletto, preserved in the Correr museum in Venice, was already known and had been published in the XVII Century (Wheelock 2013; Zahn 1685). However, we can discard its use by Vermeer because they only allow smaller drawings, and on paper, not on canvas. Steadman (2001) explains convincingly the relationship between the size of the *camera obscura* and the paintings by Vermeer.

As already explained above, all other optical devices, working without projecting images, are incapable of producing an image with the dimensions of *The Music Lesson* from a single viewpoint.

We have limited ourselves in this article, it is important to note it again now, to analysing only the construction of the perspective, which is a technical drawing, which does not require any particular ability or special talent (only accuracy, essential for drawing a Cartesian grid in perspective, but totally unnecessary for painting a face or a hairstyle).

A perspective can be more or less correct, but there are no "great perspectives". The genius in painting intervenes later, when painting. Constructing or tracing a perspective by any of the previously mentioned methods involves, more or less, no greater level of skill than fixing the canvas on the frame and stretching it does. Anyone having the knowledge and the adequate instruments can do it. Myself, to take a case in point.

Sok Kan Lai, our friend and excellent realistic painter, says that to start a painting she has to use the closest thing to a projected image in a *camera obscura* she knows: the projection of a slide. Over this projection, she traces the outlines. After this, she leaves the slide aside and starts painting.

With CADoP, we have analysed a watercolour of hers, *The Racket* (2012), and checked the incredible accuracy of the perspective of the strings of that racket (**Fig. 11**). It is impossible to achieve this accuracy "by eye", without using an optical machine.

Our conviction is that Vermeer proceeded more or less the same way. He traced the perspective in a *camera obscura* marking the extreme points of the lines he saw projected and connected these dots using a ruler. After that, he got out of there, rotated the canvas, placed it on the easel and started the truly difficult: painting.

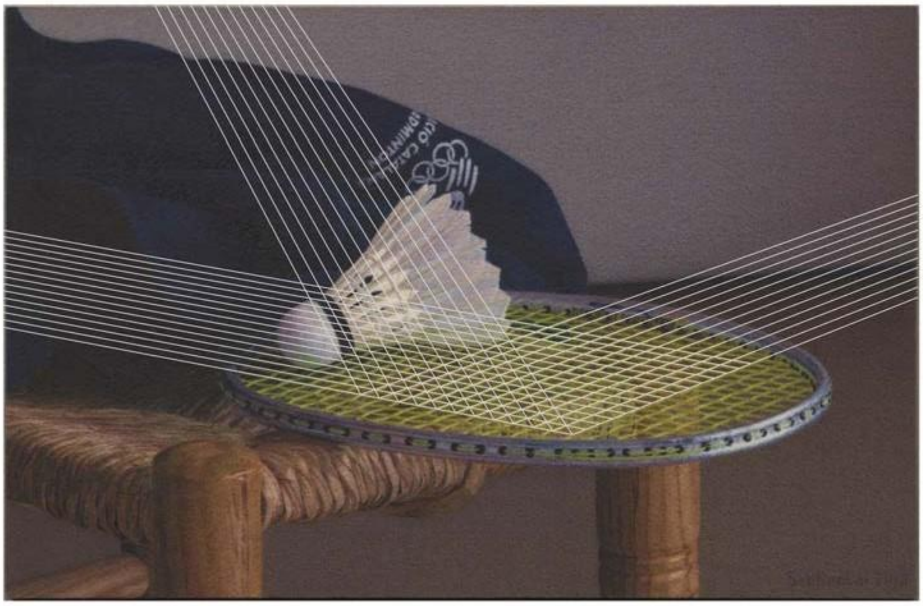
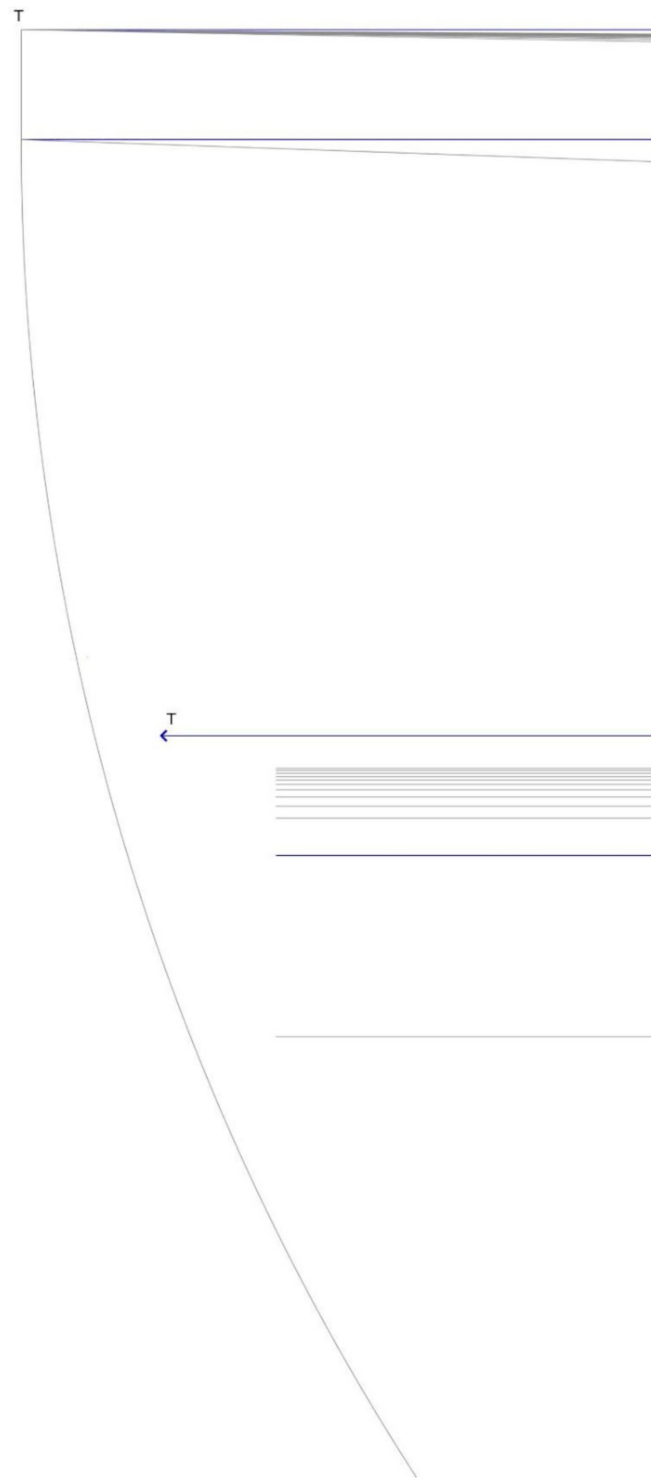


Fig. 11 CADoP analysis of the strings in *The Racket*, by Sok-kan Lai. (2012)

Did Vermeer use any other machine to finish his paintings? We cannot ascertain anything on this matter, but we can say that it seems very unlikely. If Jenison could paint his own music lesson, without knowing how to paint and using a mirror, Vermeer could perfectly paint his own without any optical instrument, using only his sight.

Finally yet importantly, the distance between the viewpoints of the perspectives in Vermeer and Jenison is small, similar to the distance between our left and right eyes. If anyone thinks we are exaggerating the importance of trifles, let them try to play badminton with one eye closed.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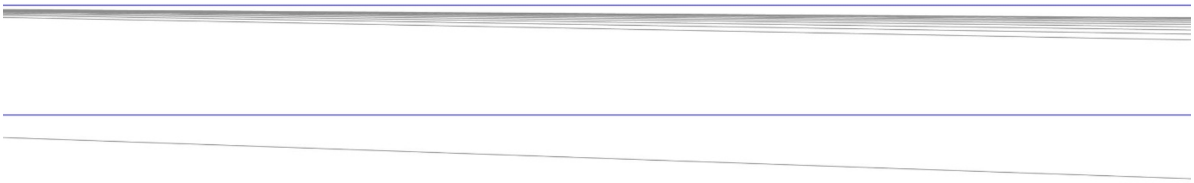

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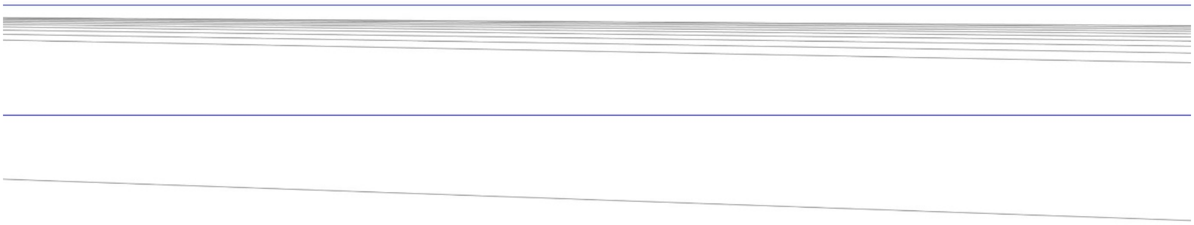

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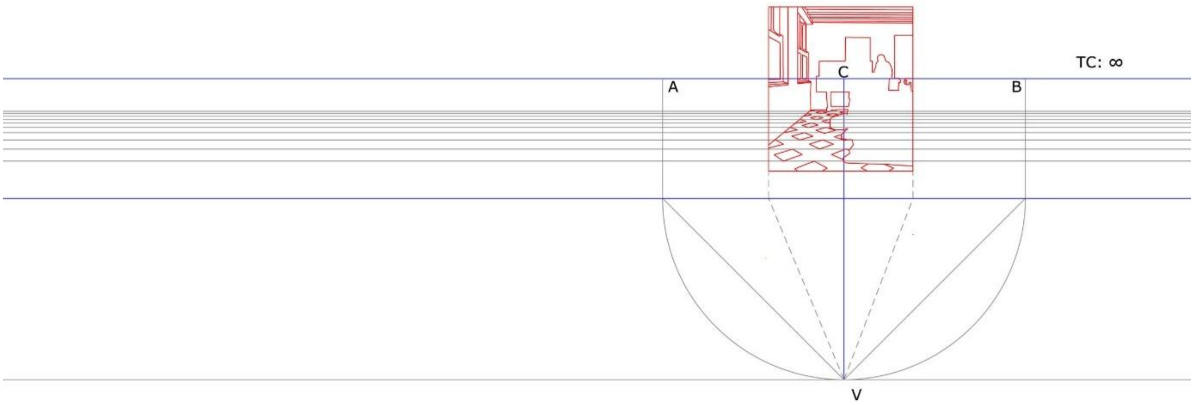
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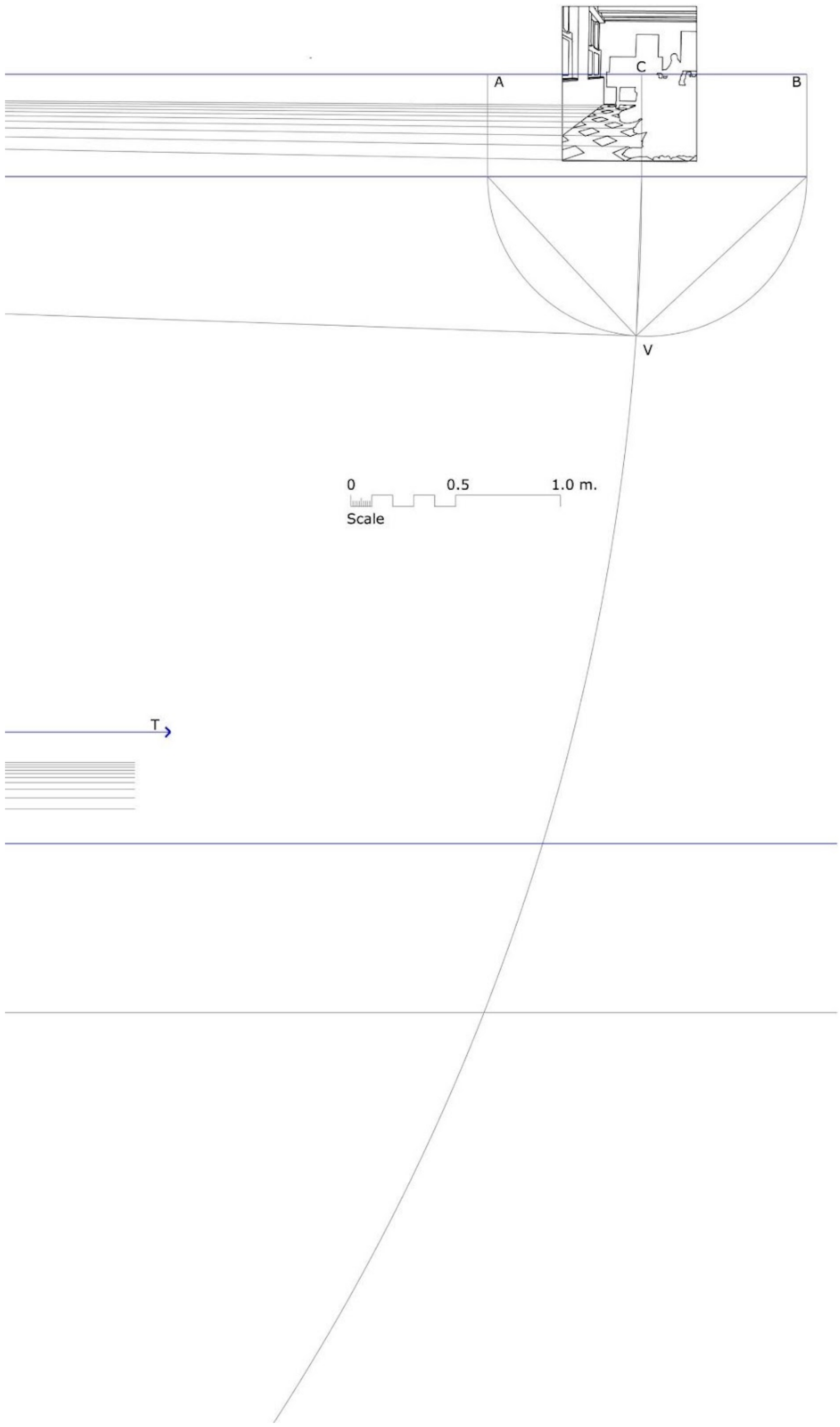

Fig. 6V (Vermeer, black) and **6J** (Jenison, red) (pages 20 to 24). The viewpoint is located in the intersection of the semi circumferences with diameter AB and TC. The vanishing point for Vermeer's transversal lines is visible on page 20. The T point in Jenison is invisible. As his perspective is a frontal one, point T is in infinity.

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