# Perspective Ingenuity. Methods and Tools for the Construction of Applied Perspective

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*Abstract*

*Between the Renaissance and the Baroque eras, perspective is expressed in different forms in the applied arts, from architectural perspectives, to the great anamorphoses and to theatrical scenographies. Its "practical construction" assumes a central role, attracting the interest of artists and mathematicians who alternated theoretical speculations with practical experimental solutions. The perspective building sites of the time became real natural-scale laboratories, where projective operations acquired physical form. Reproduced on site by means of ropes, shafts and lamps, they allowed the experimental verification of the enunciated theories. In these workshops of illusion, theoretical abstraction found its raison d'etre, revealing that fortunate union between art and science on which perspective tradition is based. This operational practice is evidence in a fragmentary way of the perspective treaties of the time, in particular with regard to the chapters dedicated to application. A critical transversal reading has permitted definition of a common modus operandi, based on the projective principles of perspective itself and which resolves the problem of construction of the traces in terms of absolute generalization.*

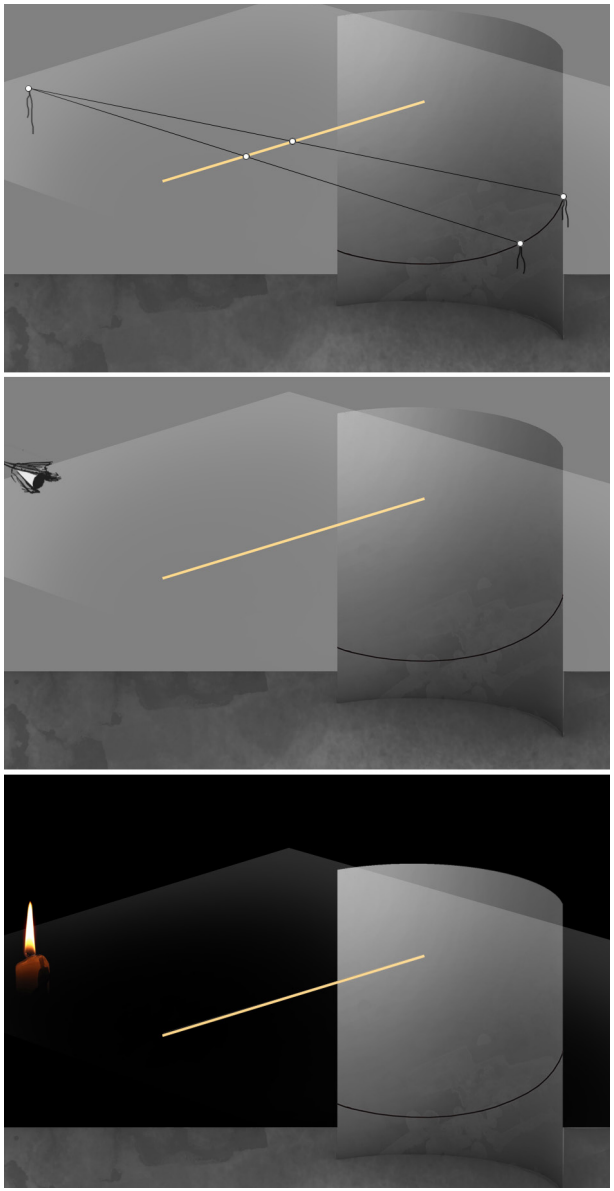
*Keywords: perspective, architectural perspectives, scenographies, anamorphoses, perspective machines*

## Introduction

In the Renaissance and Baroque eras perspective reached its apex and its maximum expressive potential. Intended as a privileged tool for reality representation, it was used to deceive and astound, expressing in different forms in the applied arts, ranging from architectural perspectives, to large anamorphoses and theatrical scenography. The wide diffusion of perspective construction sites in the European courts, made the "construction" of perspective a central question, such as to attract the interest of artists and mathematicians, who experimented and theorized in a search for increasingly effective methods and tools for the physical reproduction of perspective machines.
Numerous treatises flourished, some of them speculative, dedicated to the definition of the projective theories at the basis of perspective, others manualistic, mainly oriented to the operability of the method. The practical interest of the artists found fertile ground in places where theoretical perspective acquired physical form. At the same time, these places also attracted the speculative interest of mathematicians, who considered them as perspective laboratories in real scale, to experiment and verify the validity of the enunciated theories. In fact, in the perspective construction site realized in those years, the projective operations acquired physical form. Reproduced in space using ropes, shafts and lamps, they allowed the representation of the *apparent lines* of perspective [1].
Therefore, the practical construction of perspective interested, in a transversal way, all the applied arts that found,

*Fig. 1. Projective operations with ropes, lamps and sight (author's elaboration).*



in the projective principles of this science, their theoretical foundation. The main problem, common to the prospective building sites of the time, was the frequent inaccessibility of the points of distance and/or points of concurrence, which operationally precluded the construction of perspective through its geometric rules. Hence, it was necessary to conceive effective procedures to reproduce particular perspective images on generic picture planes, such as for example, the surface of a vault or a not necessarily flat wall. This problem had extraordinary appeal and became an opportunity to experiment with different procedures in practice. Among these, those of a projective nature assumed a leading role due to its ability to resolve the question in terms of absolute generality [2].
We have received evidence of these procedures through some of the perspective treatises of the time, where the problem finds space, in a discontinuous way, in the chapters dedicated to applications. A transversal reading of these contributions has revealed the existence of a common *modus operandi*, able to resolve the problem in terms of maximum generalization through surprisingly modern projective methods.

## Projective methods of "perspective construction"

The problems related to the realization of architectural perspectives, theatrical scenographies and anamorphoses found a common reason in the projective procedures used for their "construction". These procedures usually point up two different approaches to the problem, according to which:
- the perspective was built directly on the building site;
- the perspective was built by transporting a sketch reduced in scale or a grid superimposed on it.
The first approach generally involved the construction sites of theatrical scenography, while the second approach was more frequent in the case of architectural perspectives and anamorphoses, although the transversal contamination forms of these two methods were recurrent. Whether it was direct construction or transport, the question was resolved by materializing the projection and section operations on the construction site. Here, the construction of perspective traces was reduced through the projection of a geometric entity, usually a line materialized by a taut rope, from a projection center on a generic shaped picture plane, such as a wall, a ceiling, a vault or a backdrop of theatrical scenery. In this projective operation the point of view was given by the per-

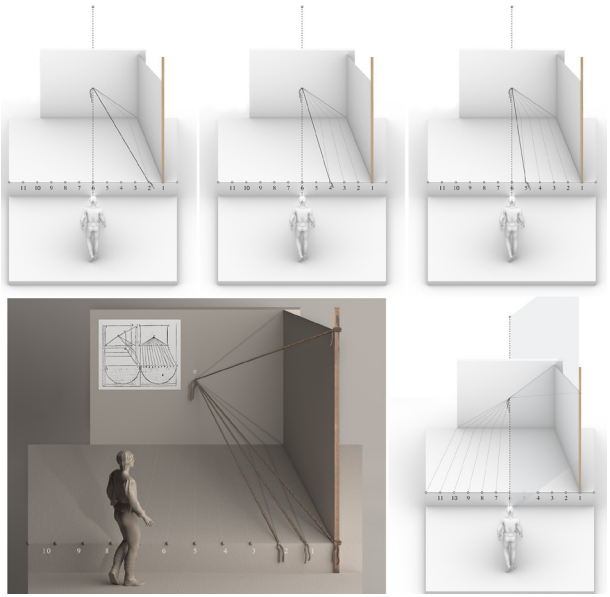
spective, a taut rope represented the entity to be projected –an objective line in the case of direct construction of perspective or a line of the grid in the case of construction by transport– finally the picture plane was the wall or ceiling to be painted.
Three types of instruments were used to physically perform these projection operations, described in most of the applied perspective treatises of that time: ropes, lamps and sight.
With ropes, or more precisely with a "projecting rope", the points of a second taut rope were projected until their intersection with the wall to be painted. An adequate number of points would have allowed the representation of the perspective of this line on any surface. Instead, with the lamps it was possible to obtain the continuous perspective image of the projected straight line, because of their shadow produced on the picture plane. Finally, by sight, the image of notable points of the projected line was determined, with the help of an assistant. The projective operations by sight, like the others, were based on the belonging of the projection center, the line to be projected and its perspective to the same projecting plane. In fact, the perspective image of the straight line is confused with the objective straight line if it is observed from the projection center. From that position the observer could give indications to an assistant close to the picture plane, able to mark notable points of the perspective image (fig. 1).
If from a projective point of view, the procedure appears exemplary, the same cannot be said from an operational point of view. The ropes, especially if imagined particularly long, are subject to bending, therefore they could hardly give an accurate result over long distances. Likewise, the poor illuminating power of the lamps could not project sharp shadows at those distances. Finally, the same problems regard sight projections, ineffective from this distance. However, ropes, lamps and sight projections constantly recur in the perspective treatises, and the reason is simple: the projection operations could be performed from any point on the same projecting plane.
We observed how the perspective of a straight line and the straight line itself appear confused in the same image if observed from the projection center of perspective. This happens because the observer's eyes, the line to be projected and the perspective image belong to the same projecting plane. If we imagine moving the projection center on any point of this projecting plane we can observe that congruence between the objective line and its perspective image remains unchanged.

The possibility of projecting generally oriented classes of straight lines, from a projection center defined "auxiliary" and placed in every point of the projecting plane, permitted a significant reduction in distance. This reduction made effective the use of ropes and lamps and favored projective sight operations. This method freed the projective operations from the position of the point of view, testifying to the extraordinary capability of perspectival artists of the time, to operate, in an exemplary way, through the use of projecting planes.

## Projective methods in operating practice

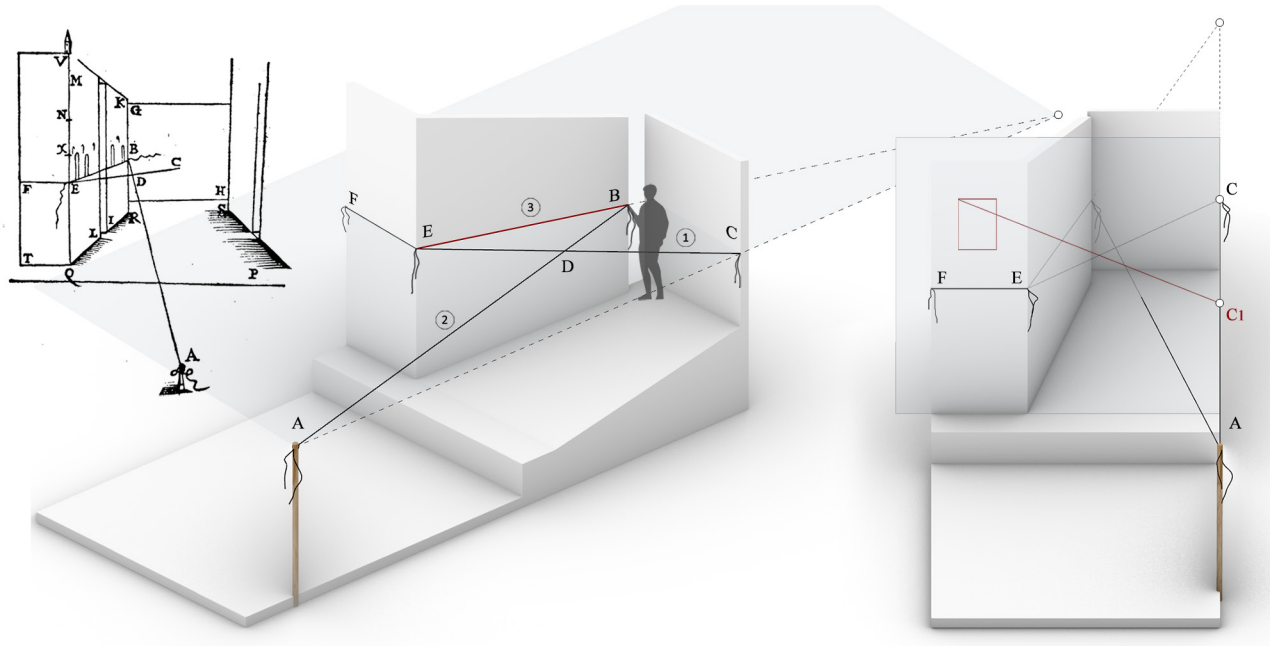
In the first half of the sixteenth century the most significant contributions to perspective in practice resolved by projective methods are given by Daniele Barbaro and Egnazio Danti. In chapter VI of the *Pratica della perspectiva*, in which the tragic scene is treated, Barbaro describes the method employed by Pompeo Pedemonte to construct

*Fig. 2. Pompeo Pedemonte's method for perspective construction of straight lines in a theatrical scenography (author's elaboration).*



the scenes: "*homo industrioso, e pratico s'ha imaginato un modo di accordare le fabbriche delle scene con le pitture dei muri e pareti di modo che le pitture pareno fabbriche e ciò che si vuole* (this industrious and practical man has imagined a way to arrange the buildings on the scenes with the wall paintings so that the paintings look like buildings and what you want)" [Barbaro 1568, p. 155].
Pedemonte's method consisted in dividing the stage floor into a series of parts, 12 in the proposed example and, on the side ones, elevating the perspective of different buildings on the stage. In order to execute these partitioning operations, a "rope like that of a mason" –as defined by Barbaro– was fixed to a nail on the backdrop plane, at the height of the horizon line. This rope was then anchored to the different division points of the floor on the stage front. Placing oneself at the point of the view, the taut rope had to be observed, since it makes a shadow. In the text, in part ambiguous, the use of a lamp is not explained except for the resulting shadow it produces and restores the sought after perspective.
In one of the dialogues of the *Mascara*, written in 1596, Ettore Bottrigari compares the method used by Daniele Barbaro with the one described by Egnazio Danti a few years later in his *Commentari* to *Le due regole della prospettiva pratica di Vignola* [Vignola 1583]. In the dialogue, Bottrigari reports Barbaro's construction highlighting its limits, with reference to a series of uncertainties concerning the position of the point of view and the height of the lamps that would project the shadow [Bottrigari 1596, p. 251]. Bottrigari's comments suggest that the lights were mobile on the scene and had to be positioned at the right height, established by the overlapping of the taut rope with its shadow, observing the scene from the center of projection [3]. In this context, the most significant aspect of Barbaro's

*Fig. 3. Egnazio Danti's method for perspective construction of straight lines in a theatrical scenography (author's elaboration).*



contribution consists in delineating a practice in which a straight line perspective was obtained by a projection of a second straight line, materialized by a rope. This second rope was not the objective line to be used to construct the perspective, but any line belonging to the projection plane, defined by the projection center and the objective straight line [4] (fig. 2).
Even in *Mascara*'s dialogue one of the actors seems to prefer Egnazio Danti's method to Pedemonte's, which proceeds "*per gli sbattimenti et ombre degli spaghi e fili tirati poco certi* (by the flappings and shadows of taut twines and strings with little certainty)", unlike Danti, il quale "procede sempre con gli incrociamenti e termini certi de' fili e spaghi tirati (who always proceeds with defined crossings and terminations of taut twines and strings)" [Bottrigari 1595, p. 258], although both come to the same result. Danti's contribution is particularly significant because it concerns different aspects of practical perspective and because it confirms the interest of mathematicians in the applications of this art [5]. The incrociamenti certi (defined crossings) of Danti's method are described in the chapter dedicated to the construction of the perspectives of scenes [Vignola 1583, pp. 90-94]. Around the mid-sixteenth century, the buildings arranged on the sides of the scene were partly three-dimensional, partly painted [6]. The three-dimensional ones were covered with cloth, on which doors and windows were represented.
Thus, Danti teaches the construction of the perspective of a window by projecting ropes with other ropes. Also in this case the projected rope, EC in fig. 3, is not the objective straight line, which would be orthogonal to the front of the scene. It is instead a generic straight line of the projecting plane which passes through the principal point C and another point chosen on a building of the lateral wing, through which the window perspective sill must pass [Vignola 1583, pp. 90-91]. The continuity with the scene painted on the backdrop is given by the principal point, where the images of the straight lines perpendicular to the picture plane converge. Instead, the perspective of the same lines on the front of the scene had the principal point precisely on the front of the scene.
Before dealing with scenography Danti describes "*la più difficile operazione che possa fare il prospettivo […] [sulla quale] fin qui da nessuno (che io sappia) n'è stato scritto poco né assai* (the most difficult operation that the prospectival artists can do […], [on which] until now no one, [that I know], has ever been written about)" [Vignola 1583, p. 89]. Therefore, he deals with the problem of constructing perspectives on vaults and describes a procedure used by Ottaviano Mascherino to paint the Bologna room in the Vatican. This procedure involved transferring the degraded sizes of three rows of columns out of the work, on a cardboard reproducing the profile of the vault, and then repositioning the cardboard on the vault. The control of the verticality and horizontality of the represented straight lines was conducted once again using the projecting planes, observing a tri-orthogonal system of taut ropes. This system consisted of a plumb line hanging from the principal point of the perspective and of a pair of ropes, orthogonal to this and between them, presumably mobile, taut along the impost plane of the vault (fig. 4). "*Perché se bene nell'opera le linee perpendicolari & le piane vengono storte per conto delle concavità della volta, come esse rispondono alla linea del piombo, & a quelle del livello, appariranno all'occhio sempre di stare a piombo, & in piano* (although in the work the perpendicular and flat lines are distorted due to the concavity

*Fig. 4. Egnazio Danti's method for the construction of perspective on the vaults (author's elaboration).*

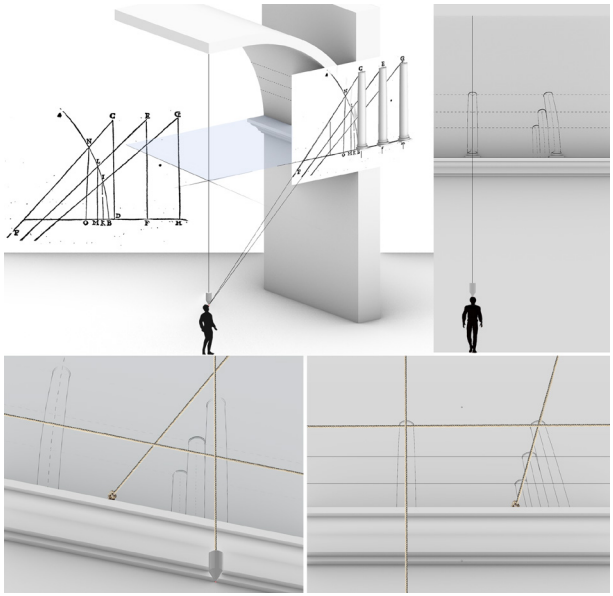
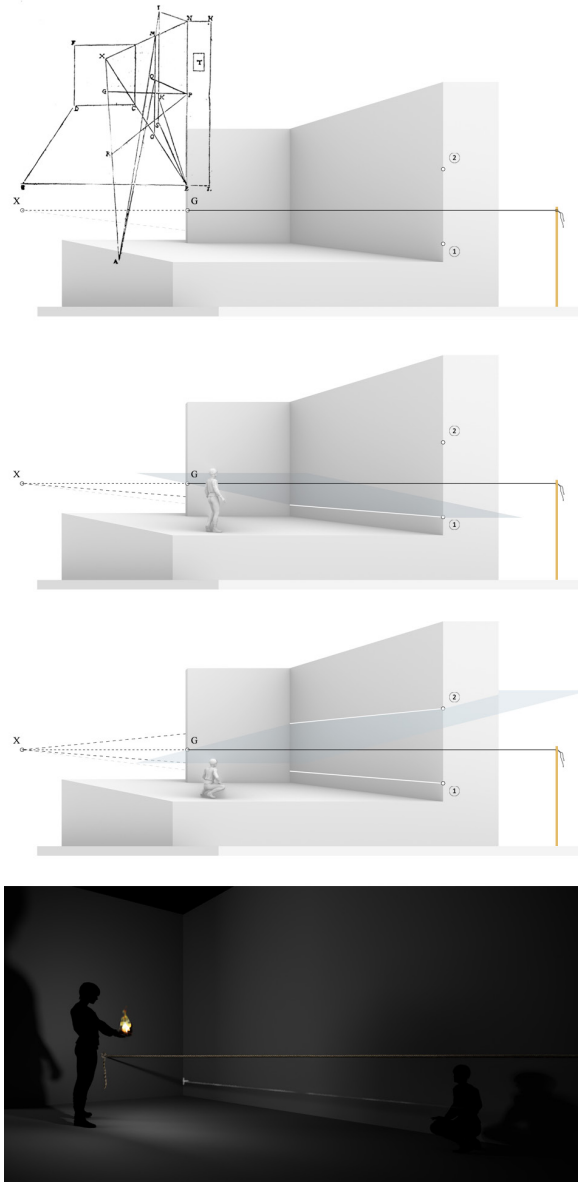


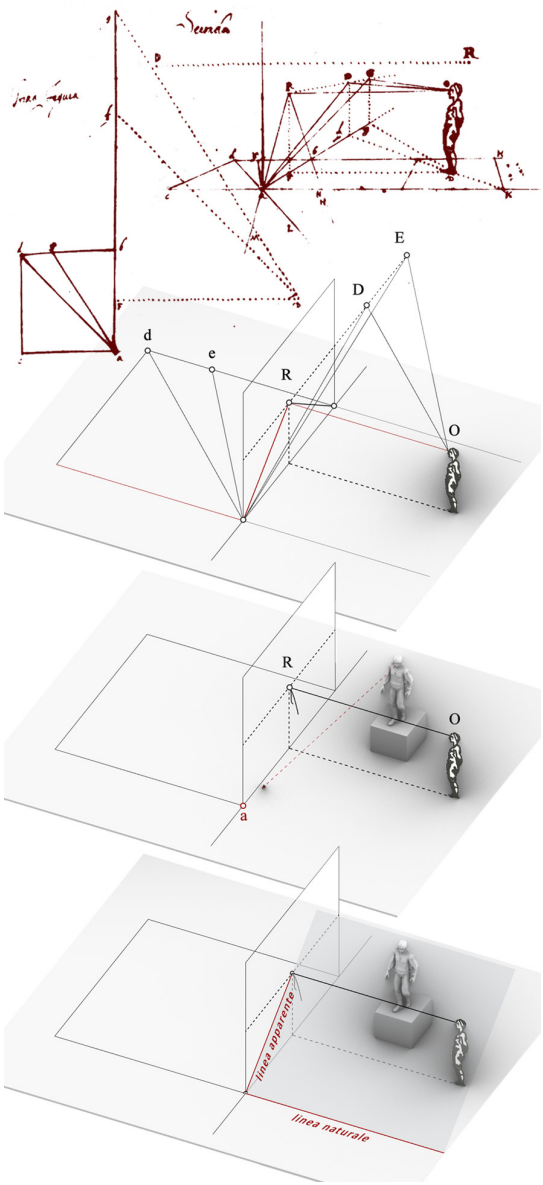
*Fig. 5. Guidobaldo del Monte's method for the perspective construction of straight lines in a theatrical scenography (elaborated by the author).*



of the vault, when they respond to the plumb line and level lines, they will always appear to the eye to be at plumb and flat)" [Vignola 1583, p. 89].
Both Barbaro and Danti do not describe invented procedures, but methods currently in use at the time which, around the middle of the 16th century, testify to the consolidated use of ropes, lamps and sight in the practice of perspective and the ability to move the entities to be represented along the same projecting plane. This operating procedure, described in the work of Guidobaldo del Monte, owes to this mathematician, its scientific reasoning and rationalization. In *De scenis*, the sixth book of *Perspectivae libri sex* [Sinisgalli 1984], Guidobaldo describes a method for constructing scenes in which he makes explicit, in terms of absolute generalization, the method that we can define as the "method of projecting planes" [7]. Having to represent the contracted scenic box, according to the tradition of the Renaissance court theater, with doors and windows painted above the wings, he describes a way of operating by sighting from any point of the projecting plane by eyesight or alternatively with ropes and lamps that which we define as the straight line projecting a given straight line. The construction of the concurrence points described by Guidobaldo in the first book of the treatise operated through straight lines parallel to the given straight line passing through the projection center, that we define today as "projecting". Thus, on stage, the projecting line in question was built by means of a taut rope; in the wing or on the stage floor, the point where its perspective would have to pass was established; the projecting line was observed from any point of the scene, from a height such that the image of the line and that of the point appeared coincident (fig. 5). An assistant would have easily marked on the wing one or more points belonging to the perspective sought [Sinisgalli 1984, pp. 218-232]. This *modus operandi*, which allowed the representation of generic classes of lines in space, was used both for the construction of the scenic box contracted and for that of the lines on the wings and the backdrop.
Guidobaldo's lesson was partly accepted by Accolti, who in 1625, in *Lo decanno degli occhi*, still applied it to the scenes through the projection of a pair of ropes with lamps, for the representation of classes of orthogonal lines to the front of the scene [Accolti 1625, pp. 89-94].
Next to the publication of Guidobaldo's treatise, Ludovico Cardi, or Cigoli, was working on his unfinished practical treatise on perspective [8]. In the *Terza Regola* (third

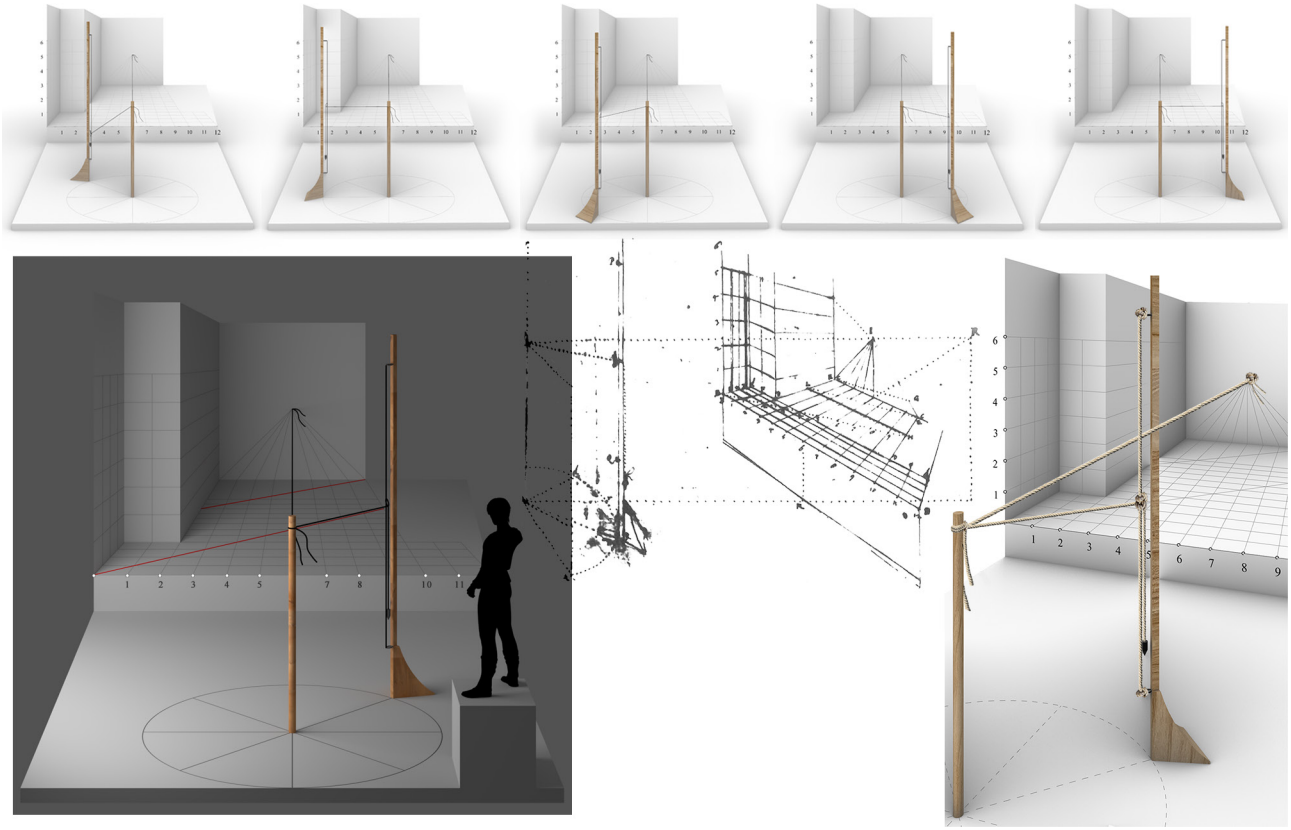
rule), described in the second book and applied to the scenes, Cigoli teaches how to construct the perspective in practice, reproducing the theory of concurrence points, presumably inspired by Guidobaldo's work [Andersen 2007, p. 376]. He describes the construction of the apparent straight line (i.e. perspective) of a natural line (i.e. objective line), given the direction of the related projecting line. This straight line was realized by a taut twine between the projection center and the section, namely the picture plane. This was laterally projected by a lamp or by sight, thus providing its perspective image on one or more sections (fig. 7).
This construction found direct application in scenography, where Cigoli describes a method similar to the one already illustrated by Guidobaldo. The original contribution concerns rather an instrument used in the scene to construct, with the aforementioned method, generically oriented classes of lines in space. This instrument consisted of a vertical shaft fixed in the center of projection connected by a twine to a second shaft, able to support itself and be free to rotate at a constant distance around the first one. The twine that connected the two shafts and that we can imagine horizontal or inclined between them, materialized infinite classes of objective straight lines in space. The latter, viewed by an observer placed beside them, provided infinite perspective images of lines having the twine as projecting line [Profumo 1992, pp. 125-134] (fig. 8).
In the first decades of the seventeenth century the possibility of operating along the projecting plane is a consolidated practice, which concerns both the theatrical scenographies and architectural perspectives. With regard to the latter, the work of Abraham Bosse entitled *Moyen universel de pratiquer la perspective sur les tableaux ou surfaces irrégulières assumes particular importance*. Published in 1653, it is a unique work of its kind, because entirely dedicated to the problem of the construction of perspective traces. This work addresses the question of perspective transport on generic shaped surfaces, according to increasing levels of complexity. Object of the transport is a perspective grid at the base of Desargues' perspective, constructed through the method of perspective scales that he theorized in those years [9]. The grid in question was the perspective image of an orthogonal grid superimposed on a drawing in scale, representing the perspective to be projected (fig. 9). This reticulum was reproduced on an ideal auxiliary plane, through taut

*Fig. 6. Cigoli's third rule for perspective construction of a straight line (author's elaboration).*



ropes converging at the principal point of perspective. The ropes of the reticulum were then projected by means of other ropes or lamps free to move along the principal distance on the projecting plane, or otherwise by sight [Bosse 1653, pp. 55, 56].
The possibility of moving the lamp to increase the sharpness of the shadows, explicit in Bosse's work, recurs in the transport operations used about fifty years later by Andrea Pozzo in the St. Ignatius Church in Rome. This is described by Pozzo himself, who in the first book of *Perspectiva pictorum et architectorum* to the one hundred and one figure, illustrates the way to make the graticola in the vaults. The comment on the figure describes the theoretical principle of projection of the grid which, positioned at the level of the impost plane, would have been projected with a candle from the center of projection on the vault. Pozzo then commented on the impossibility of practicing this operation because of the excessive distance of the point of view from the vault and because of the wooden floor that would have prevented projection of the shadow. Therefore, he describes the procedure he used for the construction of the false vault in St. Ignatius, using an

*Fig. 7. Cigoli's tool for perspective construction of generic lines in a theatrical scenography (author's elaboration).*



additional grid, obtained by projecting the first one with ropes from the projection center. The distance between the two grids was such as to be able to walk under them with a lamp and project, twine by twine, the shadow on the vault:
"*Così fec'io in HG; e poiché essendo più del solito quella vicina alla volta, le potei camminar sotto in tempo di notte, e trasportando un lume acceso di spago in spago, secondo che quelle gettano l'ombre molto visibili, e distinte, andai segnandole con color nero, di maniera che al giorno chiaro, trovai formata tutta la graticolazione prospettica* (I did so in HG, and since it was closer than usual to the vault, I was able to walk under it during the night, and transporting a lit lamp from twine to twine; producing those very visible and distinct shadows, I went to mark them in black, so that on a clear day, I found the entire perspective grid formed)" [Pozzo 1717, *centesimaprima*].
The description given by Pozzo suggests also in this case use of the projecting planes. The ropes of the lower grid and those corresponding to the upper grid belonged by construction to the same projecting plane, therefore a lamp, positioned on a twine of the lower grid, or more simply on the intervals corresponding to this grid, would have correctly projected the corresponding twine of the upper grid on the vault (fig. 10).

## Perspective machines

The aforementioned applications of perspective concerned architectural perspectives and theatrical scenographies. A separate discussion requires the great anamorphoses, particularly in relation to those realized in the convent of the Minimi brothers in Rome in the first half of the seventeenth century by Fathers Emmanuel Maignan and Jean François Niceron. Like the architectural perspectives and scenographies, anamorphoses also recur in the treatises of practical perspective of the time. From Piero della Francesca onwards, many authors had proved their knowledge, including Daniele Barbaro, Egnazio Danti and Grégoire Huret and albeit with some uncertainty, Pietro Accolti and Solomon De Caus, to mention just a few [10].
The construction of anamorphoses was generally executed by transport. A grid placed above a scale drawing was projected on a surface orthogonal to it, from a center of projection near to the surface in question. This transport operation was, more than any other, suitable to be resolved through the use of perspective machines, especially if the anamorphoses were large in size. The use of such instruments is illustrated by Jean François Niceron in the *Thaumaturgus Opticus* published in 1646. Here described is an instrument used by Emmanuel Maignan for the construction

*Fig. 8. Abraham Bosse's method for the construction of perspective on irregular surfaces (author's elaboration).*

*Fig. 9. Method used by Andrea Pozzo for the construction of the perspective on St. Ignatius' vault in Rome (elaboration by the author).*

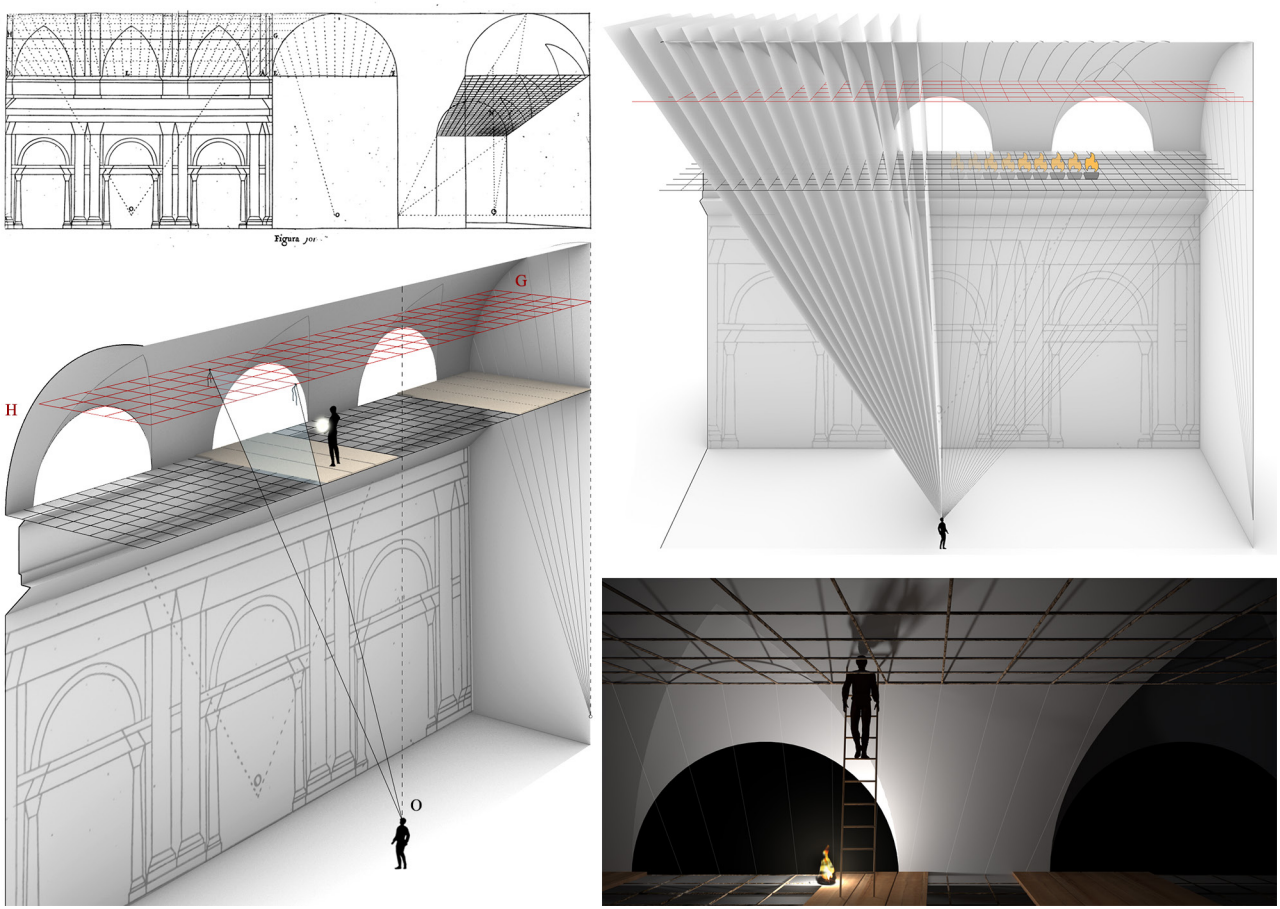
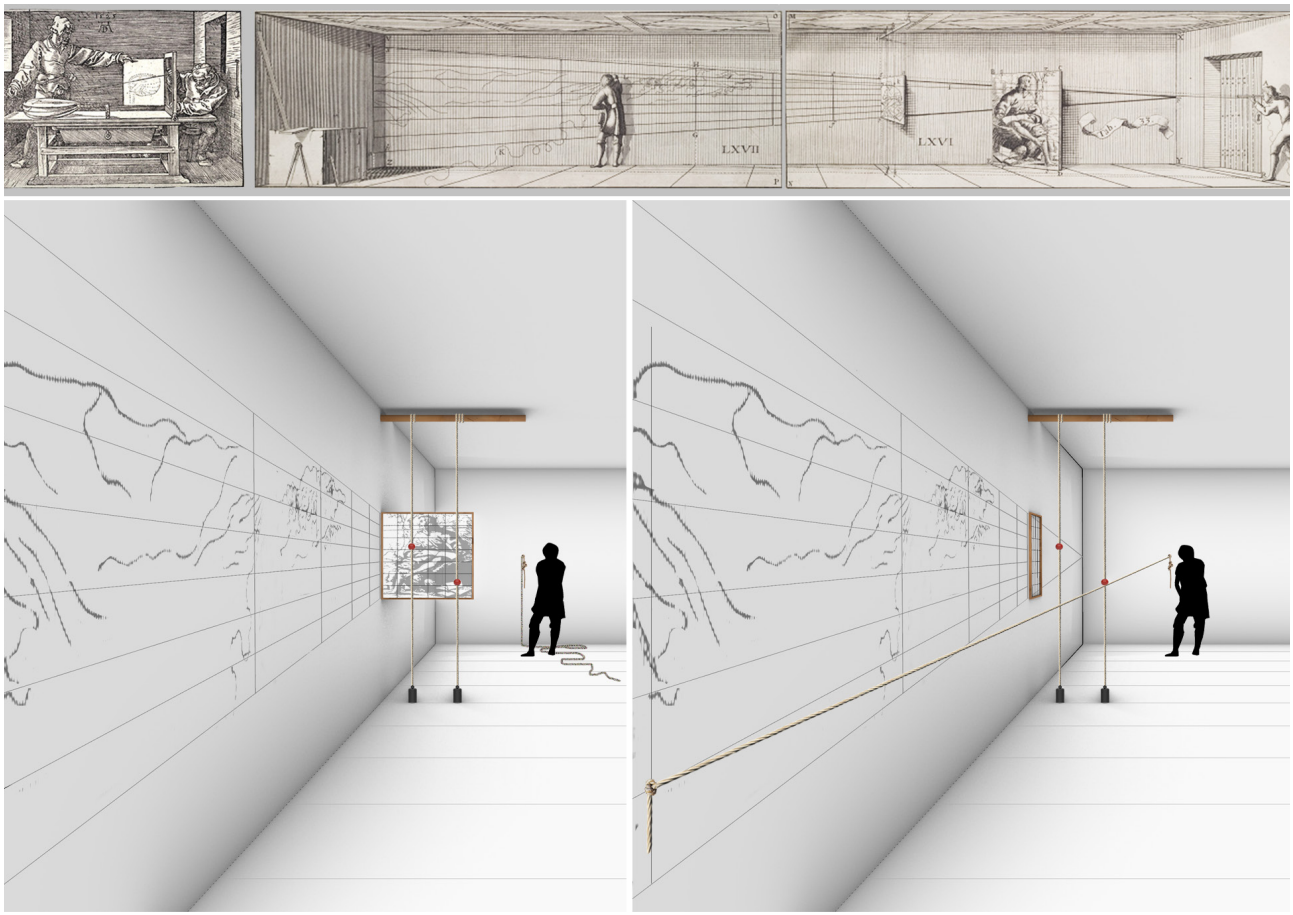


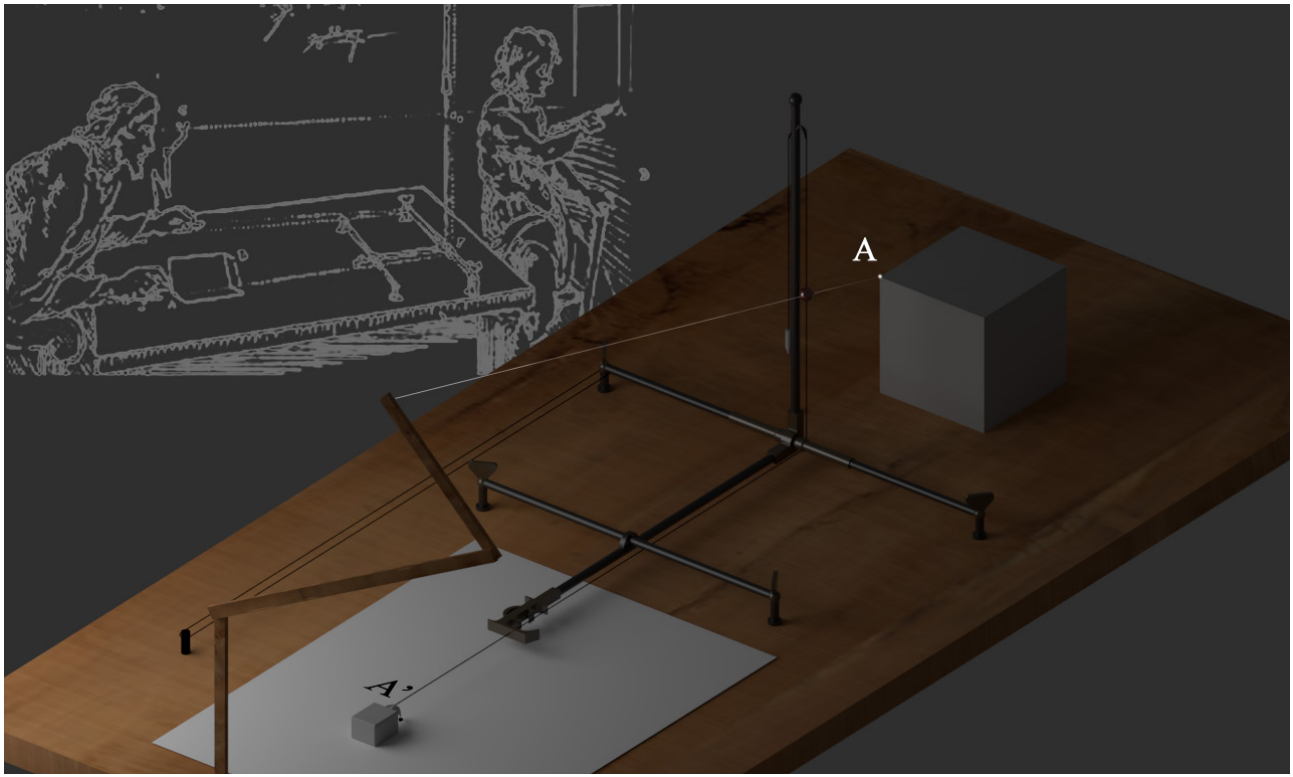
*Fig. 10. Tool described by Jean François Niceron in Thaumaturgus Opticus for the transport of anamorphosis (author's elaboration).*



of the painting of San Francesco di Paola in the Trinità dei Monti convent in Rome, mentioned by Maignan himself two years later in his *Perspectiva Horaria* [Camerota 1987, p. 85]. The instrument, which can be read as a reinterpretation of the "*sportello* (door)" designed by Albrecht Dürer about a century earlier, consisted of a sort of fork, fixed to the wall, on which a framework, in fact the door, was hinged, free to rotate around its hinges [Baltrusaitis 1978, p. 64]. On the framework there was positioned a drawing with a superimposed grid. From the fork hung a plumb line –more than one in Niceron's reinterpretation– along which a gem was free to slide. When the frame was placed orthogonally to the wall, a particular point in the reticle (or in the drawing) corresponded to the gem. Once the position of the gem was established, the frame was closed along the wall and, from the center of projection materialized with a nail, a rope was stretched, capable of projecting the gem on the wall to be painted [11] (fig. 11).

However, in Niceron's work the praises of a second instrument are sung, one not used as far as is known for the anamorphoses in question, but which is presented as the universal instrument for transport operations of this kind: the *Scenographum catholicum*. It is the revision of a perspective machine conceived at the beginning of the century by Cigoli, which Niceron saw in Paris, in the Cabinet of the Advisor to the King of France, Louis Husselin [12] [Camerota 1987, p. 90]. The instrument was a reinterpretation of Dürer's "window". An L-shaped square could slide horizontally on a pair

*Fig. 11. Tool conceived by Cigoli for the construction and transport of perspective (author's elaboration).*



of fixed guides, through ropes that were maneuvered by the draftsman's left hand, ideally describing the window during the motion.
A plumb line with a marker was placed next to the L-square, and ran up and down along it by a marker located in the draftsman's right hand. The eye was fixed at a point in space by means of an articulated shaft. With the eye fixed in the center of projection, the draftsman would slide the square left and right and the plumb line up and down with the marker, until it coincided with the image of a point on the object to be represented. This was marked on a sheet of paper, determined by the position of the marker. Between the ideal point on the window, indicated by the marker, and the point on the paper, a relationship was established, today called homological. Cigoli hypothesizes the direct and inverse use of this instrument [Profumo 1992, pp. 149-159]. Designed to construct perspective given the object to be represented, it could effectively be used to project a given perspective, in scale, onto a wall of large dimensions to be painted, such as a quadrature or a large anamorphosis (fig. 12).

## Conclusions

This partial recognition around the operational methods for constructing a practical perspective opens a window on the Renaissance and Baroque perspective construction sites, the beating heart that nourished research and experimentation in the field of perspective in those years. In the places where illusions are made the abstract projective theories that govern perspective find an operative reason, revealing that fortunate combination between art and science on which the tradition of perspective is based. The projective methods mentioned above help to illustrate this bi-univocal relationship, declining in various forms aimed at resolving, in a shared way, the perspective "construction" in terms of absolute generality. Therefore, perspective construction sites assume a central role in the history of perspective, i.e., experimental laboratories in which the perspective machine acquires physical form demonstrating, in practice, the strength of theory.

### Notes

[1] Nel suo *Trattato pratico di prospettiva* [Profumo 1992] il Cigoli definisce *linee apparenti* le immagini prospettiche delle rette da rappresentare, dette invece *linee naturali*.

[2] La ricognizione che segue considera procedimenti di tipo proiettivo, che risolvono il problema in termini generali. Oltre a questi ne venivamo impiegati degli altri, alcuni dei quali facevano ricorso agli sviluppi piani, nel caso in cui la superficie da dipingere fosse stata sviluppabile.

[3] Se così fosse la pratica del Pendemonte avrebbe anticipato le successive teorizzazioni di Guidobaldo Del Monte sulla questione.

[4] A questo piano proiettante appartenevano infatti il punto principale e, e uno dei punti di divisione del fronte del palco, estremo della fune da proiettare.

[5] Si presume che già Piero della Francesca fosse attivo nel settore teatrale [Mancini 1966, p. 18].

[6] Rispetto ai tre modelli di scene introdotti da Serlio alla fine del Cinquecento, i casamenti ricorrevano nella scena tragica e in quella comica.

[7] Sulla portata del contributo di Guidobaldo alla pratica prospettica attraverso operazioni di proiezione da un punto qualsiasi del piano proiettante si veda [Baglioni, Salvatore 2017].

[8] Il trattato del Cigoli, a cui lavorò presumibilmente dal 1605 al 1613, rimase inedito fino alla fine del Novecento [Profumo 1992, p.10].

[9] Per approfondimenti sul metodo di Desargues, l'uso delle scale prospettiche e i metodi di trasporto descritti da Abraham Bosse, si veda [Salvatore 2018].

[10] Alcuni autori, come Danti e Huret introducono un'imprecisione nella proiezione del reticolo, la cui rette orizzontali appaiono parallele piuttosto che convergere nel punto principale.

[11] La gemma era posta in luogo della coppia di fili tesi usati da Dürer per definire il punto sul quadro. Questa modifica era stata introdotta, usando una *perletta*, dall'*Accolti ne Lo inganno degli occhi* [Accolti 1625, pp. 84-85].

[12] Niceron non conosceva l'opera del Cigoli, ma apprezzò subito le potenzialità dello strumento.

### Author

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