Linear perspective from Brunelleschi to Leonardo

INVENTION

Linear perspective was invented by Filippo Brunelleschi. His priority has never been seriously questioned, either at the time or subsequently, though we can be sure that it would have been if anyone had even flimsy grounds for an alternative claim. Recently discovered evidence, in the form of a letter of 1413 that particularly associates Brunelleschi with perspective, suggests that the invention occurred at or before this date.[1] The situation may, therefore, appear to be relatively simple. But behind these facts lie questions of inexhaustible complexity, not only with respect to the historical circumstances which lead to Brunelleschi's invention, but also in relation to the nature of what he actually invented.

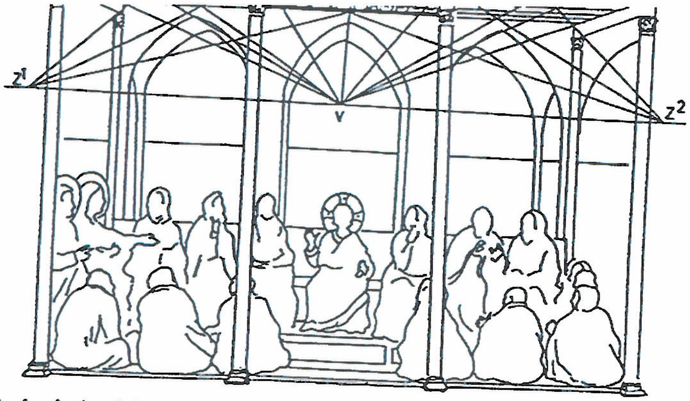
Any invention relies upon certain conditions without which it would have been impossible. The first of these is that the end towards which the invention is directed should be considered desirable—in this case that the systematic recording of visual phenomena should be seen as a worthwhile goal. A second general precondition is that the invention should be attainable in terms of the necessary levels of understanding and skill. Underlying these closely associated conditions are a series of historical factors, ranging from the most general aspects of what may be called the 'world view' to the specific circumstances (intellectual and social) of the individual or individuals involved. The handling of such factors will be discussed more fully in the coda at the end of this study; for the moment we are concerned with the relatively specific and immediate factors which gave Brunelleschi the techniques he required. Since we are dealing, first and foremost, with a method for the imitation of measurable space on a flat surface, we may legitimately begin our investigation by asking about the established methods in painting for the achieving of three-dimensional effects.

Fourteenth-century artists in Italy had developed a wide variety of stratagems for the evoking of space and for the depiction of solid forms in a more or less convincing manner. It lies outside the intention of this chapter to give a full review of these pictorial devices, but we do need to define the extent to which the *trecento* artists had adopted systematic techniques based upon rules.[2]

The natural point at which to begin is with the work of Giotto, which bears witness to a sustained, orderly and deeply pondered attention to the representation of figures and space. By the time he came to design the architectual setting for the *Confirmation of the Rule of St. Francis* (pl. 1), he had worked his way through a series of increasingly refined solutions for the creation of different kinds of space to serve particular narrative contexts. It was with interior views of the kind used here that he had moved towards an increasingly perspectival system. His paintings show that he had long since formulated and obeyed general rules which may be summarised as: those lines and planes situated above eye-level should appear to incline downwards as they move away from the spectator; those below eye-level should incline upwards; those to the left should incline inwards to the right; those to the right should incline inwards to the left; there should be some sense of the horizontal division and the vertical division which mark the boundaries between the zones; and along those divisions the lines should be inclined little if at all. Similar rules were to be described three generations later by Cennino Cennini, who regarded himself as a direct heir to the Giotto tradition.[3]

In the *Confirmation* it appears that these general rules are developing into more precise techniques for the depiction of certain regular forms. As far as can be judged in the damaged state of the fresco, the coffers of the ceiling recede towards a point of convergence near the rear of the group of kneeling friars (pl. 2). The convergence is not perfect but it looks too organised to be the result of chance or even 'judgement by eye'. The calculation of the horizontal intervals of the coffers may also have been calculated in a systematic way, but too few clues survive to permit the drawing of confident conclusions.

The idea that Giotto was responsible for the first steps towards a geometrical system near the end of his life is supported by the appearance of a highly developed pattern of convergences for the ceiling coffers in an otherwise routine work by a follower in the Lower Church of S. Francesco at Assisi (pl. 3).[4] In this case, the artist appears to have availed himself of two lateral points precisely at the edge of his fresco (now marked by inset rings) on which to anchor both sets of lateral diagonals. Although more developed geometrically than Giotto's scheme, the space as a whole is much less coordinated and the



3. Analysis of the perspective of the *Christ Disputing in the Temple* by a follower of Giotto, Assisi, S. Francesco, Lower Church.

V—focus of the orthogonals of the ceiling
Z^1, Z^2—lateral focuses of the diagonals of the ceiling design.

motif on the ceiling gives the effect of a technical device rather divorced from the figures below.

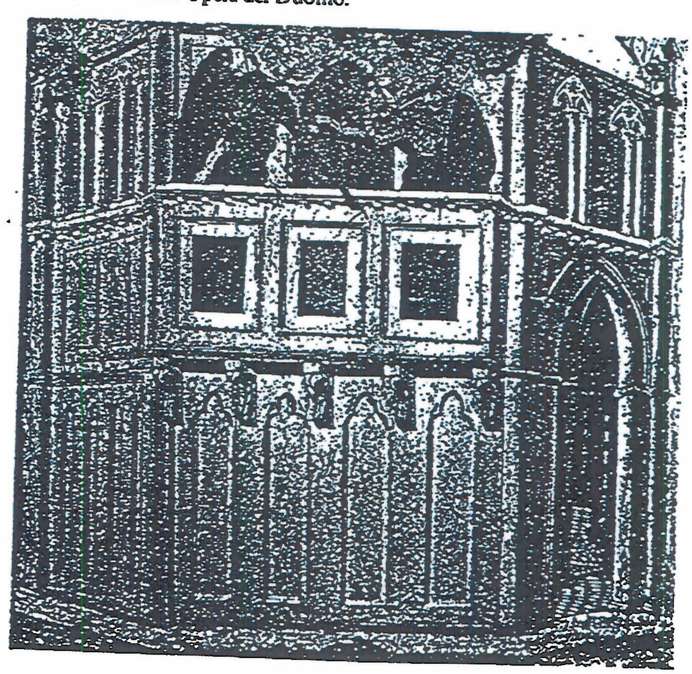
It is also important to take into account the location of the frescoes. The painting at Assisi is viewed frontally and is not located at a great height, whereas Giotto's scene is situated high on the right wall of a relatively narrow chapel. The asymmetry of Giotto's scheme may well be a response to our tendency to view the fresco from an angled position close to the entrance from the main body of the church. He has used his special sensitivity to the way in which appearances change from different viewpoints to sugggest that we are witnessing the event not from the centre but from a relatively low position nearer the side wall of the room. This has also the effect of placing us, psychologically, with the kneeling friars in a position subordinate to the main actors in the drama. This sense of the eyewitness character of Giotto's scene reflects one of the major motives behind the new naturalism. This motive was the desire, in a particularly Franciscan spirit, to present the sacred narratives to the spectator on human terms, relating us on an individual and immediate basis to the reality of the great events.

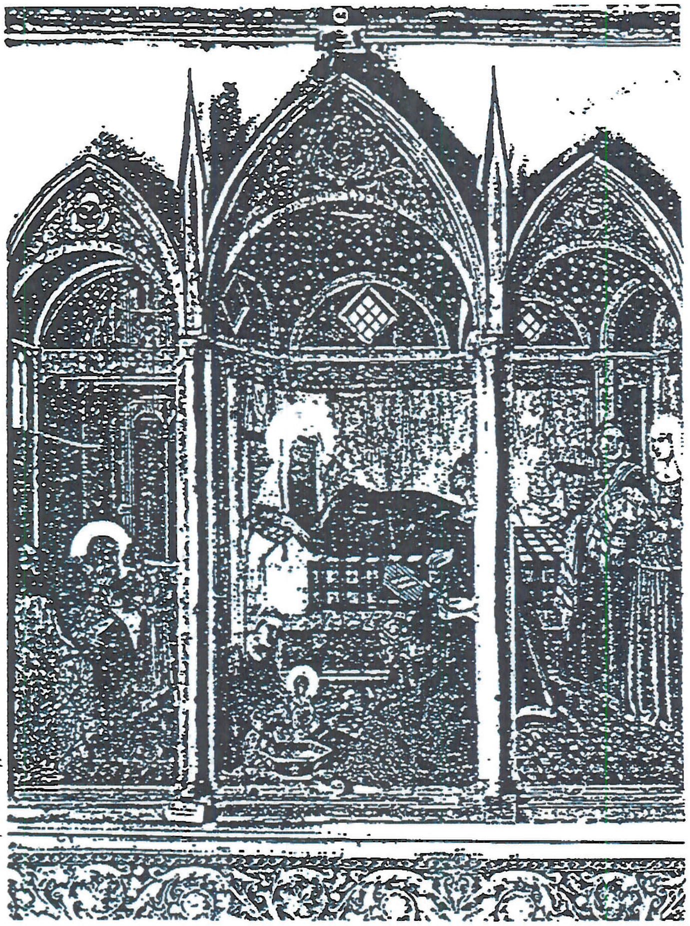
Duccio in Siena (pl. 4) similarly achieved remarkable passages of spatial description, observing the general rules of convergence to achieve schemes which only barely fail to attain geometrical precision and display a responsiveness to subject, scale and location in no way inferior to Giotto's. The particular problems tackled by Duccio in portraying the octagonal building in his *Temptation* will become particularly relevant when we come to look at Brunelleschi's invention.

The subsequent history of the techniques pioneered especially though not exclusively by Giotto and Duccio is not consistent or tidy. The more geometrical technique was not implemented widely. Although it could produce some successful passages of spatial description, it could well seem an unnecessary encumbrance to artists whose main aims and techniques were ly with the composing of effective, functioning, devotional pictures and narratives rather than with clever passages of isolated and perhaps even disruptive design. There are occasional examples of the technique being exploited, and even developed with great brilliance, above all in the work of the Lorenzetti in Siena. Ambrogio, often taken to be the more innovative of the brothers, certainly used the single vanishing point for the main lines in tiled floors with considerable precision, and the underdrawings in his paintings reveal concerted efforts to achieve geometrical control. But none of his works exploit the diagonal points of convergence with complete consistency. He appears to have preferred a less condensed pattern of horizontal divisions than results from the lateral point system. However, his brother Pietro did accomplish in 1342 what must be regarded as the *tour de force* of fourteenth-century perspective. This occurs in his *Birth of the Virgin* (pl. 5), which contains not one but two converging systems of great sophistication (pl. 6).

The tiles in the right panel converge rigorously to a point in the upper right of the central panel. Those few tiles visible in the space near the infant Virgin also appear to centre upon the same point. Two diagonal focuses are observed sufficiently accurately to give us confidence that they played an active role in the constructive process. The point at the left, which lies at the edge of the picture, may have been the one which was actually used, since the other lies off the picture surface. The check pattern on St. Anne's bed cover provides the second system, converging on a point below that of the tile construction and giving a diagonal focus at the right edge of the altar-

4. Duccio, *Temptation of Christ on the Temple* from the *'Maesta'*, 1308–11, Siena, Museo dell'Opera del Duomo.

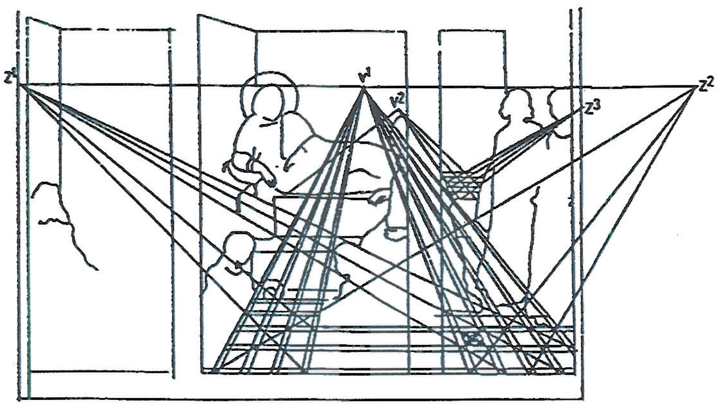




5. Pietro Lorenzetti, *Birth of the Virgin*, 1342, Siena, Museo dell'Opera del Duomo.

6. Analysis of the perspective of Pietro Lorenzetti's *Birth of the Virgin*.

V^1—focus of orthogonals of tiled floor
V^2—focus of orthogonals of pattern of bed cover
Z^1, Z^2—focuses of diagonals of tiled floor
Z^3—focus of diagonals of pattern of bed cover



... incised in the gesso of the right-hand panel, testifies to the immense effort of constructive geometry which has gone into the perspective effects, and into the organisation of the patterns within the tiles, which are based upon a series of three inscribed squares.

Like Giotto, Pietro Lorenzetti has used the system as an integral part of his description of the space in relation to the spectator. He has reasoned that the higher plane of the bed cover is seen at a flatter angle, and has accelerated its perspective accordingly (though incorrectly by strictly perspectival principles). He has used the tile pattern to unify the apparently intransigent spaces of the centre and right panels behind the frame of the triptych while creating an attractive and complicated setting for the unusual subsidiary scene in the left partition. He has also made the asymmetrical views of the rib vaults respond effectively to the off-centre viewing position, though this impression was created on an intuitive rather than calculated basis.

Effective though this system is, it was not supported by any theoretical proof—geometrical or optical—and it remained only one of various means of organising space during the *trecento*. Generally, most artists seem not to have been attracted by a method which promised much labour for an optical reward which was as yet of uncertain value.

The fourteenth-century experiments had helped to show that the systematic description of space was both desirable and possible in certain contexts. But, equally, we can in retrospect see what remained to be accomplished; namely the demonstration of an internally consistent system for all the spatial elements in a picture and, above all, a proof that the system rested upon non-arbitrary foundations. It is at this stage that Brunelleschi enters the story.

Although we will not generally be concerned in this book with the biographical details of its protagonists, an understanding of Brunelleschi's contribution is best approached through some biographical specifics. He was unusually well educated for a practitioner of the visual arts. As the son of a prominent notary he received instruction in the basics of reading, writing and practical mathematics. His earliest biographer also testifies that he was set to the learning of 'letters' (i.e. Latin), in a way which would only normally be required for someone 'who expected to become a doctor, notary or priest'.[5] The profession he entered, however, was that of goldsmithing, that is to say a craft, although one whose grandest practitioners could hope to acquire some wealth and social status. As early as 1404, the year in which he appears to have matriculated as master in the relevant guild, at the age of twenty-seven, he was already being consulted on architectural matters. His early career as an innovative metal-worker and sculptor was increasingly overtaken by his architectural activities. On his first visit to Rome, as described in his biography, he made measured drawings of Roman buildings, using his understanding of standard surveying techniques 'to plot [*congettare*] the elevations', using measurements 'from base to base' and simple calculations based on triangulation.[6] The results were recorded 'on offcuts of parchment . . . by means of squared divisions of the sheets, with arabic numerals and characters which Filippo alone understood. The basis for such procedures would have been the 'abacus mathematics' he learnt as a boy.

The evidence of the 1413 letter and the account of the early biographer, who is generally identified as Antonio Manetti, agree in dating the discovery of perspective to the earlier phase of Brunelleschi's career, before his work in architecture and technology had assumed a dominating role.

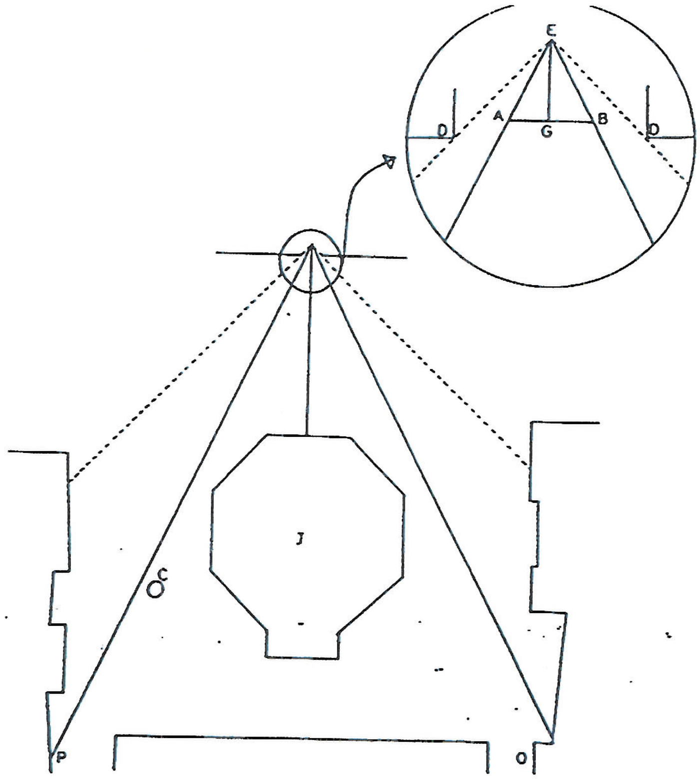
Manetti's account is central to an understanding of the discovery, in that he provides the only eye-witness account of what Brunelleschi actually accomplished. He does so in the form of a description of two demonstration paintings, both of which have long since been lost.[7] The paintings depicted two of Florence's most renowned buildings, the Baptistery of St. John and the government palace (known as the Palazzo de' Signori). From Manetti's descriptions we can deduce reasonably accurately the viewpoints which Brunelleschi adopted for each of his demonstrations, and, since more-or-less the same viewpoints are accessible to a modern-day spectator, we can gain a general idea of what he showed in each painting. It is at this point, however, that the real problems begin.

Manetti's descriptions were not written for the purpose of the precise reconstruction of the panels and he only provides rough parameters within which a variety of reconstructions are possible. More seriously and fundamentally, he provides no indication as to how Brunelleschi achieved his results, beyond indicating by implication that the high degree of optical veracity was accomplished in a systematic manner—that Brunelleschi had achieved what in popular terms is called 'scientific accuracy'.

It seems wisest at this early stage in our story not to become entangled in the technical complexities of what can and cannot legitimately be teased out of Manetti's text, but these matters are important to a full understanding of the birth of perspective, and I have therefore provided a technical outline in Appendix II.[8] Let us for the moment concentrate on what is known with a reasonable degree of probability.

The painting of the Baptistery was executed on a wooden panel which was probably a square with sides a little less than 30 cm or one foot in length. Its main feature was a view of the octagonal Baptistery as seen by Brunelleschi when he was standing 'some three *braccia*' (one *braccio* measures a little over 23 ins. or 58 cms.) inside the main door of the cathedral. His viewing position is indicated on the diagrammatic plan of the piazza in front of the cathedral (pl. 7). The perspectival appearance of the Baptistery in its main outlines can be drawn (pl. 8). Neither the physical location nor Manetti's description of the panel allow us to determine definitely whether Brunelleschi depicted a wide-angle view of what was in front of him—up to a practical maximum of 90°—or a view that was only just wide enough to embrace the Baptistery with a thin slice of the buildings on either side. The wide and the narrow limits for his viewing angle are noted in both diagrams (pls. 7 and 8).

Having painted the vivid patterns of the inlaid marble of the Baptistery in such a way that 'no miniaturist could have done better', Brunelleschi constructed a form of peepshow to heighten its illusion. He drilled a small hole in the panel at a



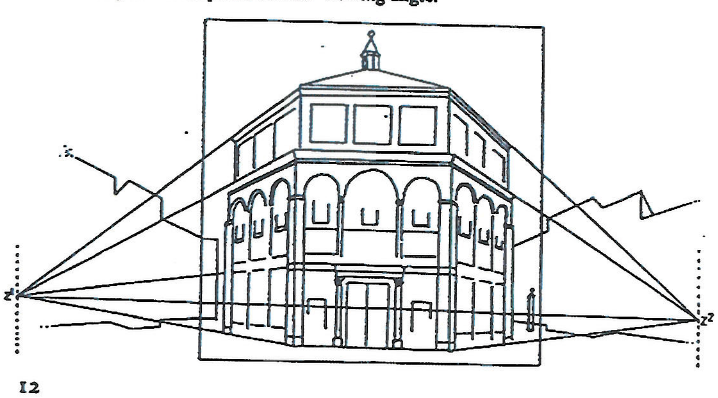
7. Diagrammatic plan of Brunelleschi's situation for his perspective demonstration of the Florentine Baptistery.

J—Baptistery
C—Column of St. Zenobius
P—Canto alla Paglia
AB—panel
D, D—sides of the portal of the Cathedral
O—Volta de' Pecori
E—observer
EG—viewing axis

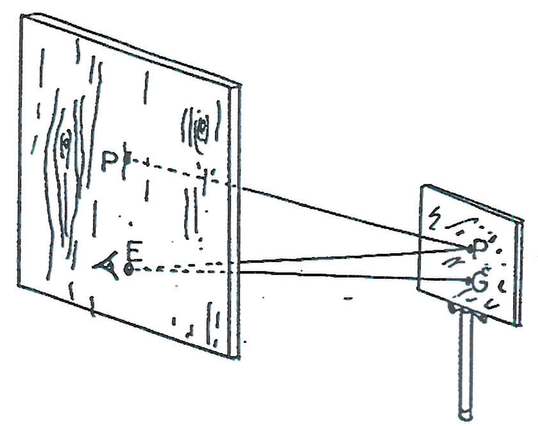
The dotted lines denote the widest possible angle (90°). The solid lines (EA and EB extended) denote the narrowest practical angle (approx 53°).

8. Diagrammatic reconstruction of Brunelleschi's perspective demonstration of the Florentine Baptistery.

Z^1, Z^2—perspective focuses of side of Baptistery, marking the edges of a panel for a 90° viewing angle.
The inner square corresponds to a 53° viewing angle.



that at which his line of sight had struck the Baptistery along a perpendicular axis. The spectator was required to peer through this hole from the back of the panel at a mirror held in such a way as to reflect the painted surface (pl. 9). To increase the effect of a magic glimpse of reality 'he placed burnished silver where the sky would be shown' so that the real sky and clouds would have heightened the optical illusion: the spectator would have been forced to view the painted Baptistery from a position generally corresponding to that from which the artist had viewed the real building. The degree of precision with which he intended and succeeded in controlling the spectator's viewing *distance* remains a matter for vigorous debate, and will be assessed in the appendix.



9. Brunelleschi's peep-hole and mirror system for viewing his perspective demonstration of the Florentine Baptistery.

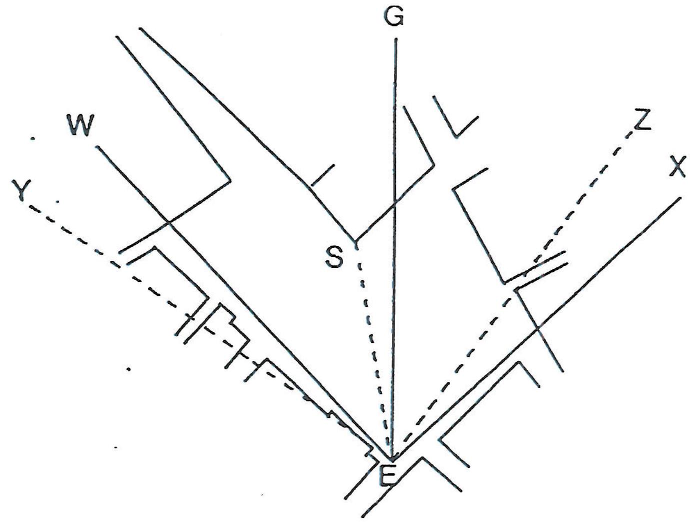
E—eye hole in the panel EG—visual axis

Point P on the painted side of the panel is reflected at point P[1] on the mirror.

Note: the dimensions of the mirror should be half those of the panel to reflect the whole panel.

The appearance of the Baptistery panel would have recalled earlier attempts to depict octagonal buildings, most notably in Duccio's *Temptation*. An attempt to take up the challenge of specific *trecento* modes of describing forms in space may be adduced even more directly in the case of the second panel, which was executed on a much larger scale and showed the Palazzo de' Signori (now the Palazzo Vecchio) from the diagonally opposite corner of the *piazza* (pls. 10 and 11). Manetti's description again leaves room for a variety of interpretations, but he does convey a clear impression that the angle of view was wide, passing along the sides of the square, and that the Palazzo was the focus of attention. Some impression of its effect may be gained from a fine drawing by Jacques Callot after the end of the next century (pl. 12), although Callot's viewpoint was probably higher than and to the right of Brunelleschi's.

For his Palazzo de' Signori demonstration Brunelleschi did not use a peepshow device—Manetti reasonably says that the panel was too large and cumbersome—but he cut away the area of the sky above the buildings. In addition to enhancing the illusion, this cut-out technique would have permitted the



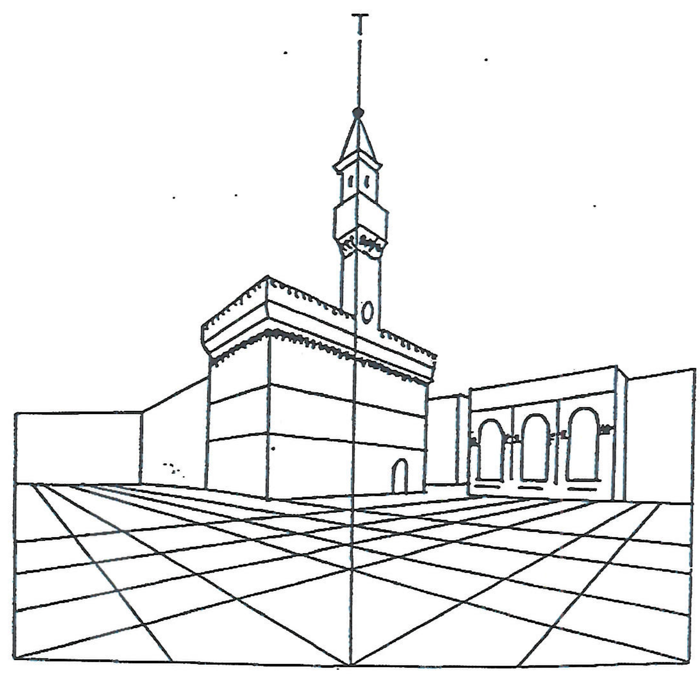
10. Diagrammatic plan of Brunelleschi's situation for his perspective demonstration of the Palazzo de' Signori (Palazzo Vecchio), Florence.

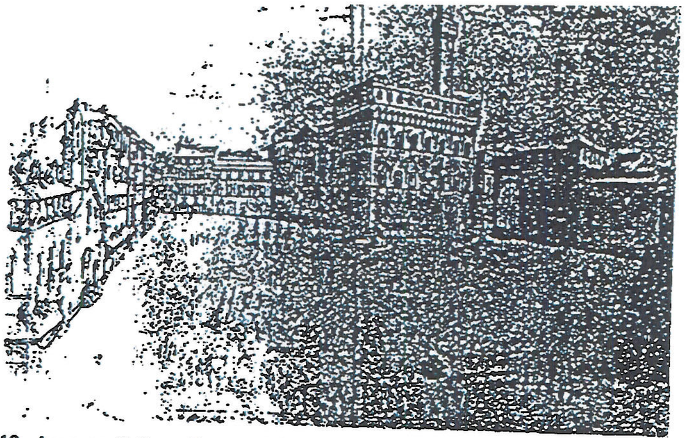
E—viewpoint
ES—axis of sight meeting the corner of the Palazzo Vecchio
YEZ—90° angle for axis ES
EG—axis of sight along diagonal axis of the piazza
WEX—90° angle for axis EG

11. Diagrammatic reconstruction of Brunelleschi's perspective demonstration of the Palazzo de' Signori, Florence.

GT—vertical through axis of sight

Note: the diagonal pavement lines denote the orientation but not the position of the pavement pattern.





12. Jacques Callot, *Piazza della Signoria*, c.1619. Darmstadt, Hessisches Landesmuseum.

verification of the resulting skyline against that of the actual buildings. The picture itself, with the angular disposition of its central feature and its two lateral points of convergence, bears a clear relation to *trecento* methods. Not only had lateral focuses been used, as we have shown, but a number of artists including Giotto and Simone Martini had endeavoured to present buildings in a similarly angular manner. However, the pictorial sources, relevant though they are, do not account for the new element the biographer stressed in Brunelleschi's method; that is to say its scientific consistency. Can we tell by what means this consistency was achieved?

Manetti's account contains no explicit guidelines in answering this question. All the historian can do in these circumstances is to weigh the potentially relevant factors and suggest a working hypothesis. The first thing to be said is that Brunelleschi's method took as its starting point a set of actual buildings, working *from* these towards a perspectival projection. He was not, therefore, creating an independent space on *a priori* principles. He required some method of plotting the salient features of the views on the flat surface of the picture plane, which thus came to function as a kind of window. The problem which now faces us is that the available knowledge and skills provide too many potential sources for his technique.

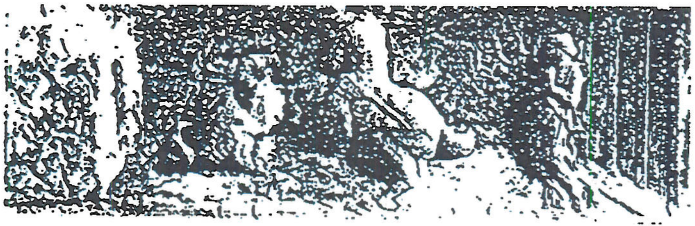
Historians have at various times postulated that he exploited the skills of mediaeval surveying; relied upon scaled elevations and plans of the buildings; exploited scientific instruments such as an astrolabe to measure visual angles; adapted the geometrical formulas of mediaeval optical science (*perspectiva*); converted the projective techniques used by Ptolemy to map the earth and heavens; and adopted the 'simple' procedure of painting on the surface of a plane mirror. Most of these procedures (reviewed in more detail in the appendix) *could* have worked, and it would be wrong to make too sharp a separation between them, since one may have reinforced or refined another. It may, however, be possible to make a tentative

... and contingent factors.

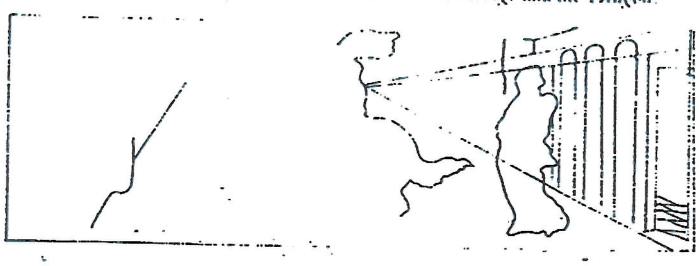
Under the heading of formative factors I would include the challenge of *trecento* modes, the use of surveying techniques (particularly in the context of urban planning) and the measured recording of plans and elevations. Amongst the contingent factors we should obviously consider a range of techniques from mediaeval and classical science, including optics, astronomy, horology and geography, but it is difficult to see these sciences providing the germinal source for Brunelleschi's ideas. They may all be classified as relevant rather than directly applicable, and they generally come into the technically difficult category. It should be noted that the friend of Brunelleschi, Paolo Toscanelli, who is sometimes credited with introducing the more abstruse sciences to the architect, was only sixteen years old in 1413. Brunelleschi's interest in the optical properties of mirrors may also have arisen from his knowledge of surveying methods. I should say, however, that it does not seem at all likely to me that his procedure actually involved painting directly on a mirror, for a number of practical and intellectual reasons.

Behind these technical factors lie a complex series of social and cultural conditions. The general question of the way in which the science of art can be related to broader social issues will be discussed in the coda at the end of this study—and some specific remarks made about the invention of perspective—but I think it will be helpful at this stage to signal some of the factors that may be adduced. The skills available to Brunelleschi were integral to the growth of practical mathematics in a mercantile society. The compounding of artisan technical knowledge with the more theoretical sciences of the Middle Ages and with ancient learning in the revived texts of Greek and Roman science was to provide a potent mixture in the intellectual revolutions of the Renaissance. Specifically in Florence, the more abstract principles of humanist learning were being brought into especially fruitful conjunction with the practical requirements of civic life. The values of the Ciceronian humanists who lead the city administration aspired towards measured assessment and what may be called the achievement of rational 'perspectives' in judging the nature of man's world and the course of human action. While it is true that we should not look at society, even within Florence itself at this time, as a unified or internally consistent culture in all respects—and it will become clear that I distrust explanations based on simple mechanisms of social causation—there is little doubt that Brunelleschi's measured representation of these two revered buildings was deeply locked into the system of political, religious and intellectual values shared by those who exercised the greatest influence on Florentine civic life in this period.

Even though the rationale behind the invention may be said to reside integrally within Florentine society, the conceptual originality of Brunelleschi's discovery judged in relation to the established forms and functions of art was such that it did not take immediate root. We need to wait until the mid-1420s to see the first works fully designed according to the principles of perspective science. I do not think this delay was simply a matter of the invention being too radical in principle. Rather



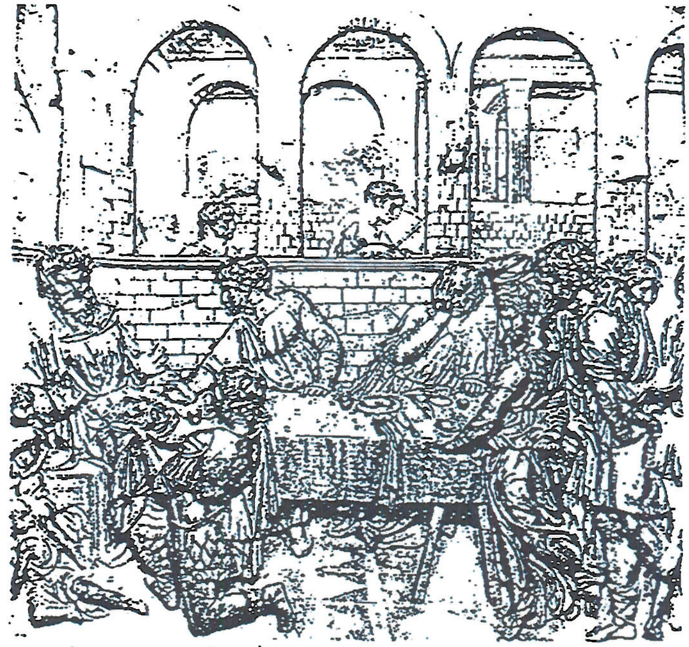
13. Donatello, *St. George and the Dragon*, c.1417, Florence, Museo Nazionale del Bargello (formerly on Or San Michele).



14. Analysis of the perspective of Donatello's *St. George and the Dragon*.

it seems a question of the actual procedures being largely inapplicable to the day-to-day needs of artists at this time. The procedures relied upon existing buildings and, inevitably, resulted in the portrayal of these buildings. Painters were not employed to paint townscapes as such, except in very unusual circumstances, and a set of existing buildings is unlikely to have provided an appropriate or adaptable setting for the religious subject-matter which predominated. The sheer effort involved in making a projection of a given building must have seemed to promise little or nothing which their existing methods could not serve more effectively, adaptably and economically. What was needed was a means of adapting Brunelleschi's procedures to the creation of an imagined space which could act as the servant to the artists' needs. Without such a means, the potential of the invention would remain dormant.

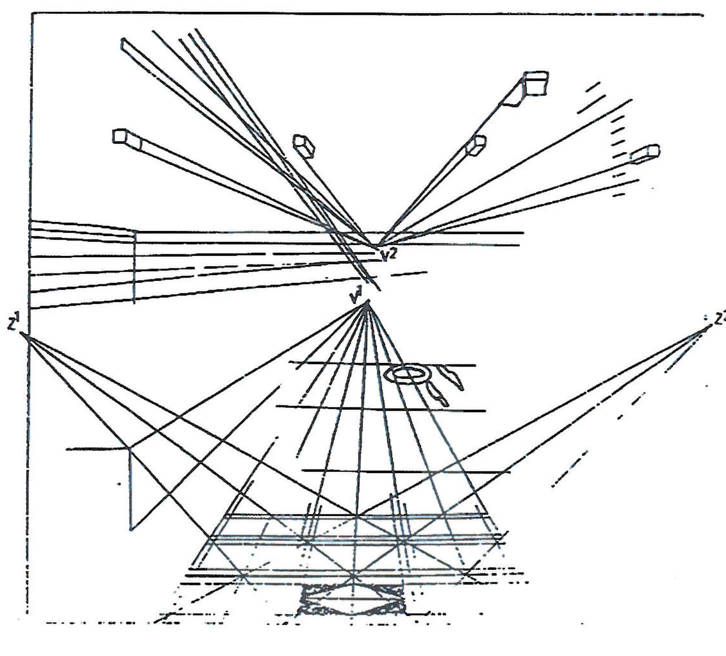
The first notable sign amongst the younger artists of an interest in novel spatial effects occurs in about 1417, in Donatello's marble relief of *St. George and the Dragon*, which was destined for the tabernacle below his sculpture of St. George on Or San Michele (pl. 13).[9] Using an innovatory and extraordinary subtle low-relief style, Donatello has created an unprecedented sense of atmospheric space behind the plane of the marble panel. At this stage, however, the techniques appear to be predominantly suggestive and intuitive rather than geometrically precise. The receding lines of the arcade, in front of which the princess glides, do converge to a definite point behind the saint's back (pl. 14), but most of the other architectural features seem to be judged by eye rather than measurement. The tiles of the pavement within the building are incised freehand and do not conform to a precise system.



15. Donatello, *Feast of Herod*, 1423–7, Siena, Cathedral Baptistery.

16. Analysis of the perspective of Donatello's *Feast of Herod*.

V^1—focus of orthogonals of tiled floor
V^2—primary focus of orthogonals in upper part of relief
Z^1 Z^2—'diagonal' points



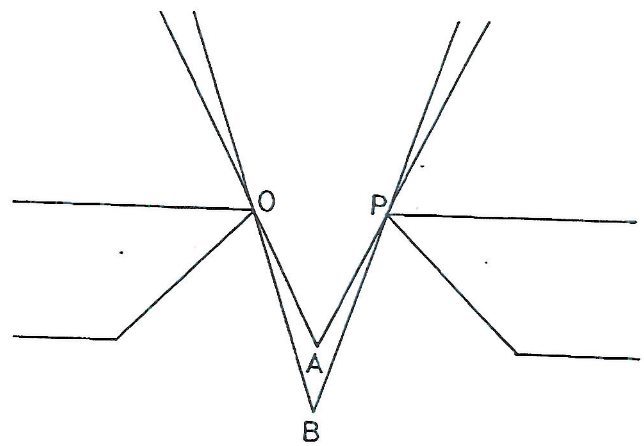
Brunelleschi's Demonstration Panels

1. THE BAPTISTERY PANEL

(a) size:
Manetti described the panel as 'about half a *braccio* square'. It is not clear whether he is referring to side length or area. If the former, the side length would have been about 29 cms. (11½ ins.); if the latter, the side length would have been about 41 cms. (16 ins.). The account does not say specifically that the panel was square, but this is a reasonable inference.

(b) viewing angle:
Manetti says that the Volta de'Pecori and Canto alla Paglia were visible on either side of the Baptistery (see pl. 7). Since he does not describe features that would have appeared under a wide angle of vision (up to a practical maximum of 90°), it may be inferred that the angle was little if anything wider than the 53° or so needed to incorporate the described features. The very short viewing distance (c.14½ cms.; 5¾ ins.) also militates against the wider angle. However, a 90° angle was not uncommon in later paintings, and it would have possessed the advantage that the diagonal sides of the octagonal Baptistery would have converged on lateral vanishing points precisely at the edges of the panel. Any angle between 53° and 90° should not be definitively excluded.[1]

(c) the viewing aperture:
Manetti says that the hole in the panel was as wide as 'a ducat or a little more' (about 20 mms.) on the back and 'as tiny as a lentil bean' on the painted side. The visual field through a panel of even modest thickness would have been very restricted.[2] If the hole size on the painted face was, say, 6.5 mms. (about ¼ ins.) and the panel was of similar thickness—which is thin for painted panels—the viewing angle could have been no greater than 53° (pl. 554). This calculation does not make allowance for the distance between the spectator's eye and the rear plane of the panel. Even if the eye was pressed as close as anatomically possible, we must allow for a distance of a few millimetres. The restriction of angle under these circumstances rapidly becomes so severe as to preclude the possibility that even the Baptistery could be encompassed 'in a single glance' as described by Manetti. We may suspect that the widening of the hole on the reverse was to permit



553. The geometry of the viewing hole in Brunelleschi's Baptistery panel.
OP—aperture on the painted face of the panel
A—viewpoint on the plane of the rear of the panel giving an angle of 53°
B—viewpoint behind the plane of the rear of the panel

some marginal manoeuvering of the eye to encompass the full view. Such manoeuvering may in any event have been necessitated by the fact that the hole would have been well below the centre of the panel. These factors imply that the viewing conditions involved an element of compromise.

(d) viewing distance:
Manetti states that Brunelleschi devised the peep-show because 'the painter needs to presuppose a single place from which the painting must be viewed, taking into account the height and depth and width, and similarly for distance'. The implication is that the mirror was to be held at a distance from the panel which ensured that the viewing distance was precisely scaled in relation to the equivalent distance in the actual piazza. For a 53° angle the scaled distance of mirror from panel (taking into account that the mirror doubles the apparent viewing distance) would be of the order of 14½ cms. (5¾ ins.), giving a total viewing distance of 29 cms. (11½ ins.). Given the problems of occlusion through the viewing aperture and the

apparent absence of any means of controlling the distance at which the viewer would actually hold the mirror. I suspect that the peepshow was improvised by Brunelleschi at a relatively late stage in the development of his demonstration and that its optical implications were not part of the original conception. Manetti, with hindsight, may have been imputing a desire to control the viewing distance with more precision than Brunelleschi intended.

2. *THE PALAZZO DE' SIGNORI PANEL*

Manetti's description of this panel, probably the later of the two to be executed, gives fewer optical hints. His description of the extremities of the angle of view passing down the sides of the piazza leaves little doubt that the visual angle was indeed wide in this instance. If the central axis of Brunelleschi's view (pl. 10), ran directly to the nearest corner of the palace, the consequence would have been that the sides of the palace and the existing pavement pattern (as far as we can tell) would have subtended awkward angles. If, alternatively, the central axis was aligned at 45° to these features, the perspective focuses of the dominent features in the painting would have corresponded conveniently.

3. *THE PROCEDURES*

Since Manetti gives no indication of Brunelleschi's methods, and it is unsafe to identify them with later written prescriptions, such as Alberti's, we can do no better than judge the relative probabilities of different methods on the basis of the knowledge potentially available to him. The main possibilities, mentioned in the text are as follows:

(a) the skills of surveying
He would almost certainly have learnt these in his abacus school and have applied them to the measurement of Roman buildings. The standard techniques relied upon simple triangulation in which a vertical measuring rod often acts as an intersecting plane (like the picture plane) for the lines of sight. Some of the surveying methods also exploited such mirrors as were available.[3]

(b) the use of scaled elevations and plans
These could form the basis for a two-stage projection of the main outlines of the buildings on to a flat plane, using the principles outlined in the demonstration in the first of these appendices.

(c) the use of more elaborate instruments
These would measure visual angles with considerable precision. We know that Alberti later used an instrument resembling an astrolabe in his survey of Rome, and it would have been in character for Brunelleschi to have been captivated by the technology of such instruments.

(d) the geometrical formulas of mediaeval optical science ('perspectiva')
These analysed the visual pyramid and discernments of size and distance in elaborate detail. In some accounts, mediaeval *perspectiva* has been granted a central role in Brunelleschi's invention. These claims have been examined in the section on Ghiberti. In general I believe that mediaeval optical science created far more problems than it solved for Renaissance artists.[4]

(e) the projective techniques of Ptolemy's geography and cosmology
Such techniques were becoming increasingly known if imperfectly understood at this time.[5] They are indeed of quite a high order of difficulty.

(f) painting directly on an actual mirror
Although this method has the merit of apparent simplicity, the practical problems of the painter's head and hand masking vital parts of the view, and the failure of Manetti to recognise that the Baptistery was painted directly on to a mirror, militate strongly against this possibility. It would not, in any event, have necessarily involved any exercise of perspectival geometry and would not justify Manetti's claims. The second panel did not involve any mirrored elements.

I personally favour the factors in the order listed above, with a very strong preference for his adapting the kind of surveying techniques which we know to have been available to him.

4. *THE 'VANISHING POINT'*

It should be noted that what later came to be known as the vanishing point for lines perpendicular to the picture plane (Alberti's 'centric point') would not have been particularly apparent in Brunelleschi's panels. It is doubtful if the buildings along the sides of the piazza in which the Baptistery stood were regularly aligned, and under the narrower visual angle any general recession to a central 'vanishing point' would not have been emphatic. The hole was, inevitably, coincident with the 'vanishing point', but may have been intended only to mark the axis of Brunelleschi's sight perpendicular to the Baptistery. The alignment of the major forms in the other panel would not have emphasised any central vanishing point. Rather, both panels probably exhibited the strong lateral recessions of objects at 45° to the picture plane, corresponding in emphasis to the so-called 'bifocal' or 'distance point' methods found in some *trecento* art. I suspect that the empirical, object-based methods of Brunelleschi in or before 1413 did not emphasise the implicit central vanishing point to the explicit degree apparent of Alberti's later, synthetic construction of space on *a priori* principles.

APPENDIX I

The basis of the perspective construction

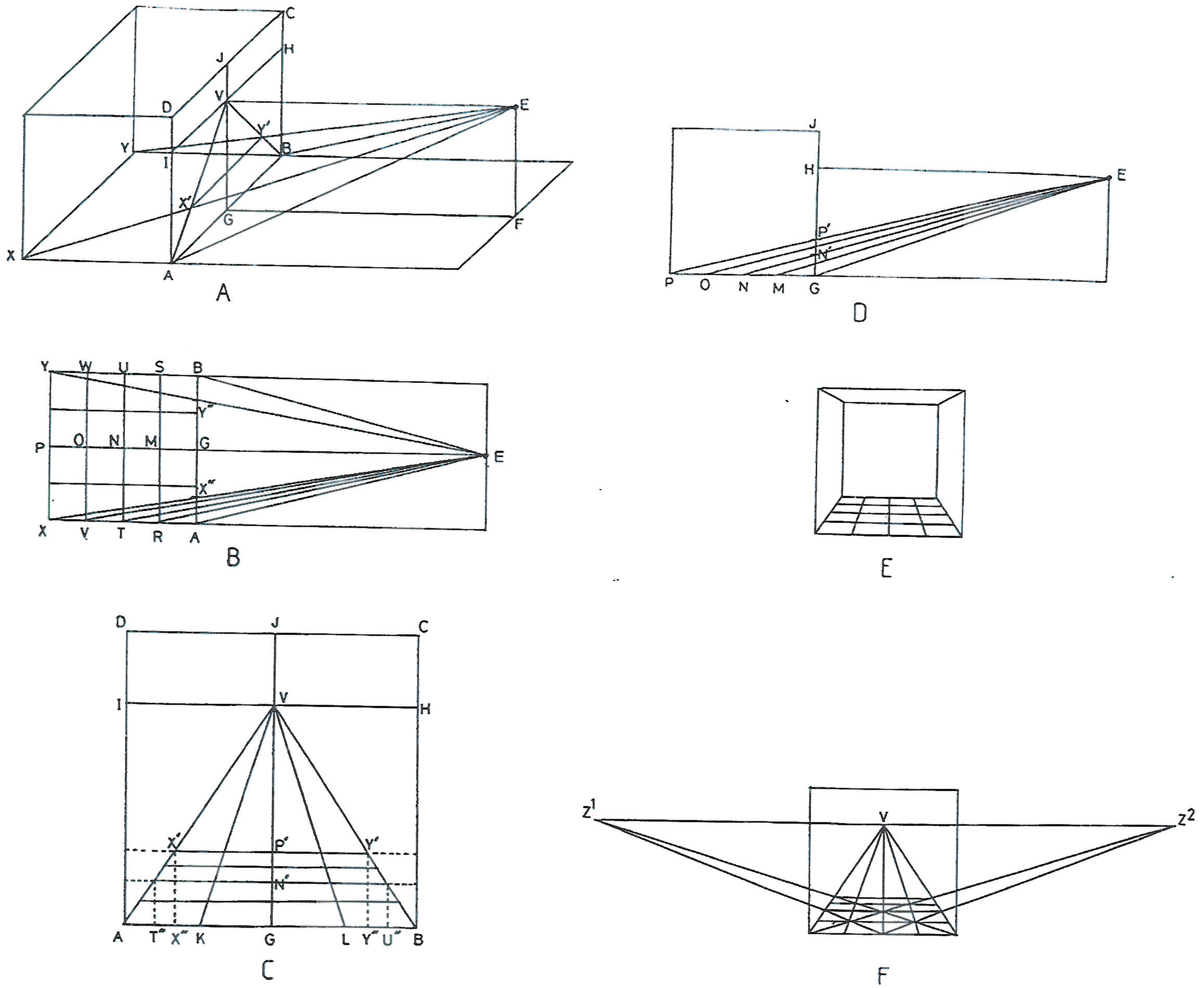
At its simplest, linear perspective is a system for recording the configuration of light rays on a plane as they proceed from an object to the eye in a pyramidal pattern. This system is shown in a basic manner in the first of the diagrams (pl. 552A), which deliberately uses a set-up recognisable to a Renaissance artist. We are imagining an observer stationed at F looking with his eye at E towards a tiled floor through a transparent plane, ABCD. The courses of the rays passing from A, B, X and Y to the eye are traced, and the points at which the rays from X and Y intersect or pass through the plane will be marked (X′ and Y′). The line AB will be seen unchanged on the plane, but XY will be seen as X′Y′. Joining A to X′ and B to Y′ will show how the sides of the tiled floor will appear on the plane. Extending these projected sides, they will be found to join at V, which is also where a line from the eye meets the plane perpendicularly.

The main terminology we are using is as follows: E is the 'viewpoint' and EV the 'viewing distance' along the 'axis of sight'; ABCD is the 'picture plane' or 'intersection'; V is the 'point of convergence' or, later, the 'vanishing point'; the horizontal line through V (HVI) is the 'horizon'; lines such as X′Y′, parallel to the base of the picture plane, are termed 'horizontals' (sometimes called 'transversals'), and the converging projections of the parallels AX and BY at AX′ and AY′ are the 'orthogonals'.

The system with which we are dealing is a form of geometrical projection of a three-dimensional object on to a flat plane. One of the standard, early ways of accomplishing this projection is in two separate steps, using plan and elevation. Let us imagine our model in plan (pl. 552B). We will plot the intersection of rays from R, T, V, X etc. at the picture plane AB. The location of these points (X″, Y″ etc.) will be noted along AB (as in pl. 552C). We then move to the elevation or side view (pl. 552D), and plot the intersections of M, N, O, P as P′, N′ etc. These also will be noted as P′, N′ etc. along the vertical from G (pl. 552C). Once the points from the first construction (pl. 552B) have been transferred to the base AB and the points from the second (pl. 552D) to the central vertical, GJ, they provide, respectively, the vertical and horizontal co-ordinates for the locations of the points, X, Y, T, U, etc. as they will appear on the picture plane. Where the co-ordinates intersect, the projected points are located (pl. 552C). The orthogonals from A and B can now be readily drawn through the projected points and extended to the vanishing point, V, through which the horizon can be drawn. The remaining elements in the tiled floor, the projections of the lines from K and L should in theory be produced by repeating the procedure in 1B, but for practical purposes we will simply join these points to the vanishing point at V. We will have constructed the tiled floor in its projected form (pl. 552E). There are abbreviated ways of arriving at the same result, but the fullscale procedure helps to show what is happening.

When we look at the resulting configuration, some interesting consequences emerge. Diagonals drawn through the projected squares will meet precisely at two lateral points (Z^1 and Z^2 in pl. 552F). The distances from these lateral points (sometimes called 'distance points') to the vanishing point will be equal to the original viewing distance EV. These lateral points are of considerable importance, both because they were widely used by artists and because they enable us readily to reconstruct the viewing distance whenever we are provided with a foreshortened square in a work of art. The diagonals also provide the orientation for objects whose faces lie at 45 degrees to the picture plane.

Understanding the procedures is not difficult, but does require a little care and patience. They can best be mastered by working through the basic moves with a pencil, paper and ruler.



552. The Demonstration of the basis of linear perspective.

A. The Basic set-up:
ABCD—picture plane
AXYB—square to be projected
FE—observer, and EV is the viewing distance
X is seen at X' on picture plane.
Y is seen at Y' on picture plane.
Therefore X'Y' is XY in projection.
AX' and BY' are extended to meet at V (the 'vanishing point').
HI is drawn as the horizon, level with the observer's eye, E.

B. Plan of the set-up
AXYB is a square divided into 16 smaller squares by WOV, UNT etc.
Y, X, V, T, are joined to E, and the points of intersection on AB are noted as Y", X" etc.

C. The picture plane
Points T", X", Y", U" etc. are marked at their equivalent positions along AB.
Points P', N' etc. from fig 1D are marked at the central vertical above.
The intersection of the horizontal and vertical coordinates T", X", Y", U" and P', N' etc. provide the locations for X', Y' etc.

D. Elevation of the set-up
G—centre-point of base of picture plane.
Points, P, O, N, M are joined to E, and the points of intersection on the vertical above G are noted as P', N' etc.

E. The tiled floor in projection
With the 'side walls' and 'ceiling' of the completed cube of space.

F. The 'distance points', Z^1 and Z^2
Note that $Z^1V = Z^2V = EV$ (fig 1A).