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The Transformation of Space and the Construction of Engineering Knowledge and Practice – From Renaissance Perspective Thinking to Gaspard Monge's Descriptive Geometry

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If we look at a picture from a modern textbook in engineering, we often find pictures of construction drawings. Here is an example from an about twenty year old textbook in construction engineering (figure 1). Now let us take a drawing that is more than five hundred years older. Here is a drawing made by the Italian Renaissance Painter Paulo Uccello from about 1430 (figure 2). If we compare these two drawings and neglect that they represent different objects – the drawing from 1975 depicts parts of an oil platform, the drawing of Uccello shows a drinking cup –, there is a great similarity. Both drawings show us numerous small geometrical figures that together give us a picture of the external shape of the object.

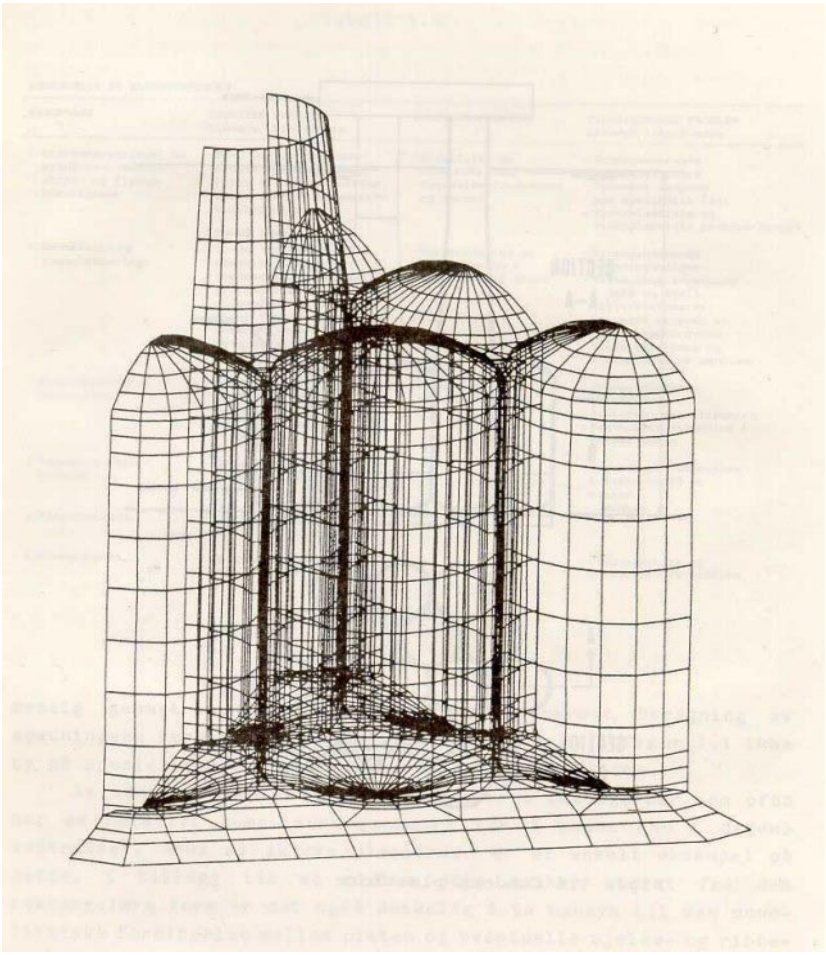


Figure 1

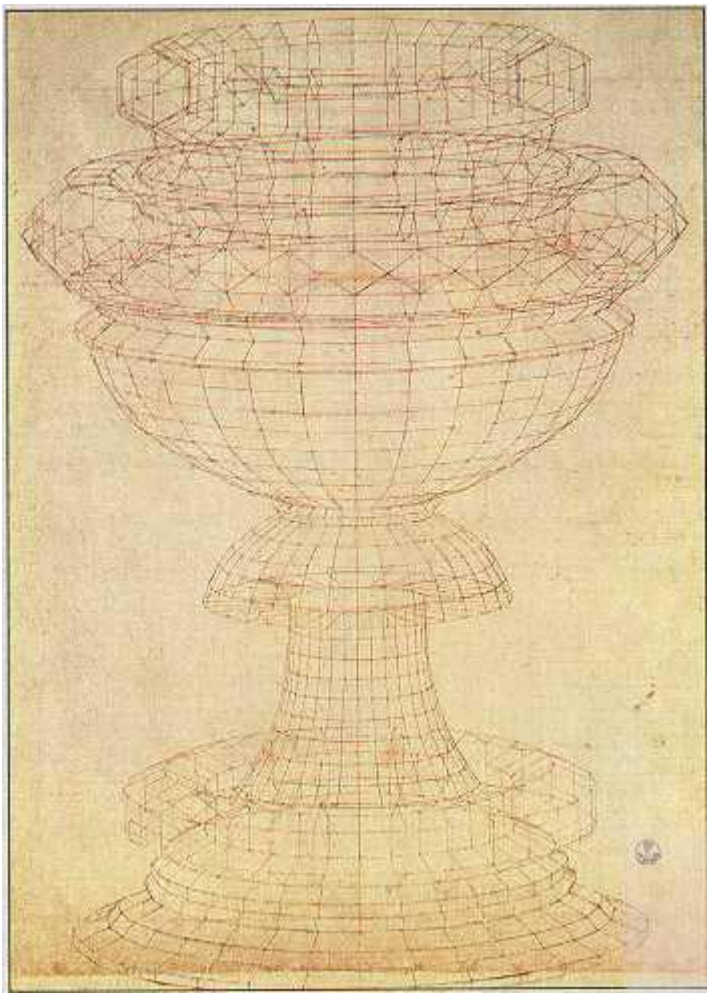
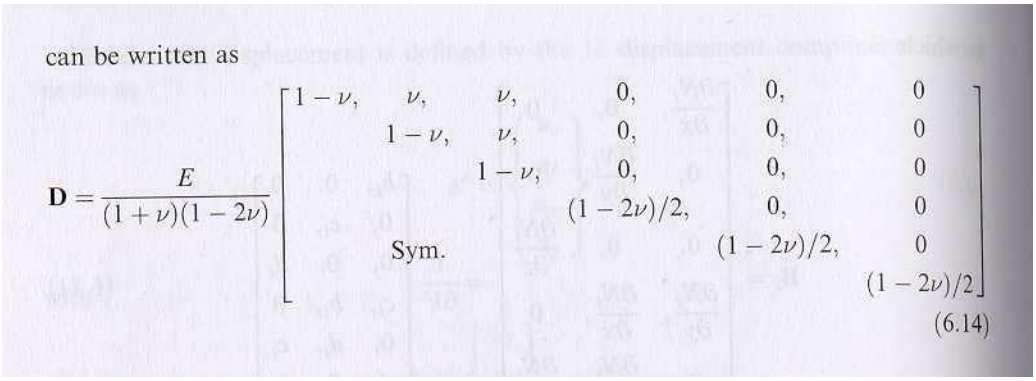


Figure 2

This similarity is of course only to be found on this level. The engineering drawing is made by a machine, the renaissance drawing is made by Uccello. The engineering drawing is a representation of a construction, that is in the making. Uccello's drawing is probably made on the base of an existing drinking cup. The engineering drawing is a tool for the construction of an oil platform. Uccello's drawing was made for artistic purposes. And finally: the engineering drawing is a representation of a mathematical model, while Uccello is only using a mathematical model for the painting. The mathematical model for the engineering drawing is the so called finite element method, and each geometrical figure is a representation of different sorts of mathematical theories and tools. Here is a typical form of one such cell. (figure 3) The cells in Uccello's drawing, on the other hand, are only based on a general mathematical representation of space, the linear perspective.



can be written as

$$\mathbf{D} = \frac{E}{(1+\nu)(1-2\nu)} \begin{bmatrix} 1-\nu, & \nu, & \nu, & 0, & 0, & 0 \\ & 1-\nu, & \nu, & 0, & 0, & 0 \\ & & 1-\nu, & 0, & 0, & 0 \\ & & & (1-2\nu)/2, & 0, & 0 \\ & \text{Sym.} & & & (1-2\nu)/2, & 0 \\ & & & & & (1-2\nu)/2 \end{bmatrix} \quad (6.14)$$

Figure 3

But in spite of these differences, the drawings are, in their general characteristics, quite similar. The obvious similarity is that they are both in some way representations of objects in space, and that these representations are in some way based on mathematical theories of space. The difference between them is, to borrow a terminology from Bruno Latour, that Uccello is using a space that is in the making, while the engineering drawing is based on a ready made space. I will try to elaborate during this presentation how the space became ready made, and thereby made possible the spatial thinking that again made modern engineering possible.

Already the Art Historian Erwin Panofsky showed in a famous article in the 1920s that modernity developed a thinking about space that we do not find in any other culture, neither in antiquity nor in any non-western cultures. Panofsky saw the linear perspective as a representation of that way of thinking. For him, the linear perspective was a specific cultural and historical way of approaching space. Linear perspective was beeing represented as systematic space.

I will draw the claims from Panofsky further. Not only was the modern space a systematic space, it also got a different ontological status than other types of space. By modernity, space became a being. Now, since constructivist perspectives have been emphasized, this claim has not been any radical claim. Obviously, space, as all other phenomena, is constructed. The interesting thing is however not to deconstruct the construction of space, but to show how this construction made several modern types of knowledge and practices possible, like those making possible the construction of an oil platform. It was not a construction that took place in a laboratory. It took place in a culture, and many inputs were necessary to form an ontology of space. I will here only give a short presentation of some of them, and show how the development of this ontology made possible the theories of Gaspard Monge, the founder of descriptive geometry, the perhaps most important subject in the modern engineering curriculum.

Let us start with the Italian renaissance and the linear perspective. What is generally regarded as the first description of the linear perspective, was made by the Italian architect and learned humanist Leon Battista Alberti. He presented a theory of linear perspective to be used by artists in the book *De picture* from 1435. Alberti defined the so-called visual pyramid, a model of how space is organised between an object and the observer. The main purpose of this visual pyramid was to serve as a tool for painters, and to enable them to make drawings with depth visions. In general, we see the work of Alberti as a formalisation of an already existing space. But Alberti did not only tell painters how to operate in space, he also indirectly told them what space is.

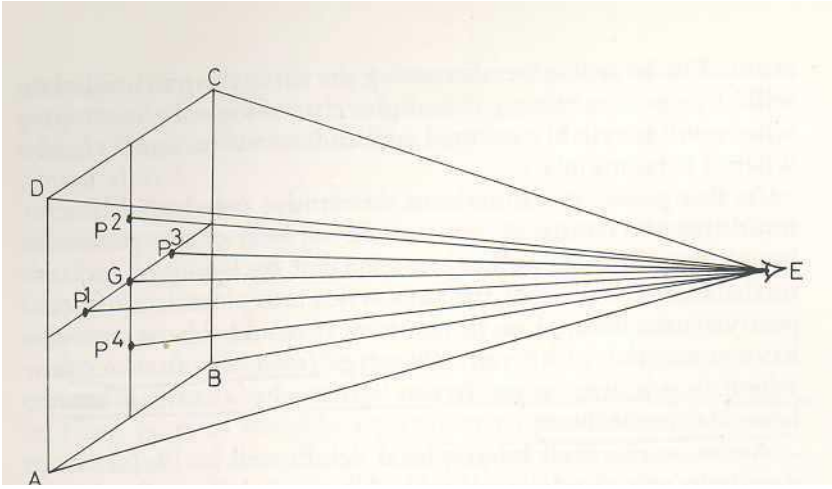


Figure 4

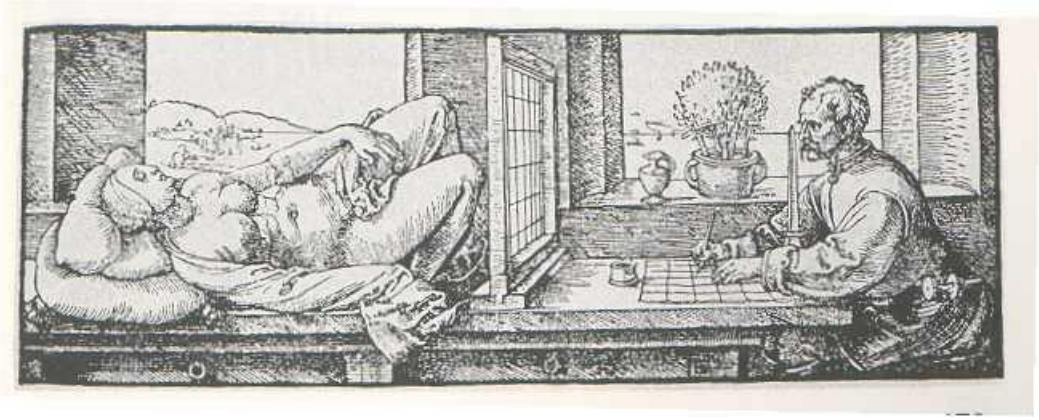


Figure 5

We can see this by looking at the visual pyramid of Alberti (figure 4 and 5). Alberti claimed to have solved a problem that had divided the ancients in two different fronts. In antiquity there was a discussion wether what was seen, the visible, was the result either of the object seen or of the looking eye. This is a debate which is continuing even today in scientific disciplines and in the theory of knowledge: is what science describes what the object tells or what the subject sees?

Alberti solves this whole problem by saying that this is not at all what it is about. What is important is what lies in-between. Alberti gives this in-between an ontological status, it is something being. By being something, it can be made operational, and the mathematical models can be applied to it. With this space, Alberti could define painting as an intersection of the visual pyramid. While Panofsky is focusing on the linear perspective, as have most historians of arts, I think it is important as well to look at the ontological status of the in-between. A structuring of space was not possible before there was a space to structure. The Italian Renaissance came up simultaneously with a space, a being of that in-between, and a theory for the structuring of it.

As well as the linear perspective does not exist in non-western cultures, the ontological status of space is very weak outside the modern western world. Also the ancient regarded space as something in-between. The term used by the Greeks was *khôra*, That word was used originally to describe a limited area of earth. *Khôra* was connected to specific physical phenomena, like earth, borders, walls or spheres. The Greek word *apeiros*, translated as infinite, does actually mean – as infinite also means – 'without ends or without boarders'. It is interesting to note that Euclid does not apply the term *khôra*. He only speaks about points, lines, surfaces and borders. Also the Roman *spatium* is a description of the in-between. And it connects as well the in-between with the boarders. It is equivalent with distance, the distance laying between to points or two boarders.

But although the ancient world had terms for that "in-between", they never gave it a specific ontological status. Every attempt to define the content of this space in-between ends up by finding it empty, which leads to great philosophical discussion wether void is a being or not. Democrit is very clear on this issue. Only what is indivisible, the *atomoi*, has an existence. The in-between of the *atomoi*, the space, is non-being. For Demokrit space did not exist. Aristoteles definition is perhaps the closest we get in the antique world to give the inbetween an ontological status. For Aristotele space (*khôra*) it is a place, a *topos*, where nothing is (The Physics, 213b). It is being with non-being.

The objects, their physical and symbolic content, were regarded as being in antiquity. The objects, real as well as fictitious, were ordered in symbolic and practical discourses, not in relation to any space. Even "pure" geometrical forms had symbolic character and were ordered to a larger symbolic discourse. Even Aristotle, who is the closest we get to someone who speaks about pure forms, puts the circle into a cosmological framework. The spheres of the world are circular because the circle is the most perfect geometrical figure.

Michel Foucault has made a description of what he called the renaissance "episteme". This episteme represents for Foucault an intermixture of words and things. It is a large discourse where neither objects nor subjects are sorted out; everything is in some way interrelated. It is a world where words and things are interwoven in a closed cosmological system. This picture fits more with the ancient world. It does not fit the renaissance world we see in the works of Alberti and other artists and theorists on the linear perspective. Here we find a separation between words and things, between the observer and the observed. The in-between is something on its own, it has ontological status.

The making of this in-between was a result of a long process. Panofsky states 1250 as an important year. Alberti and his fellows and friends of perspective thinking were very enthusiastic about this in-between and the mathematical organisation of it. Uccello is known for answering his wife calling to him out of her bed: "How sweet a thing perspective is". But they did not break with the old symbolic interrelation of the things. Piero dell Francesca, who was perhaps most skilled in mathematics among the renaissance painters and perspective thinkers, always stayed close to a Platonic/Pythagorean as well as Aristotelian view of the world where the different geometrical forms had different symbolic meanings. Even the ideal city of Francesca, from about 1470, perfectly drawn according to a linear perspective, has the circle in the centre (figure 6). The most important building, the house of the gods, is circular.

Fig 6

Up until Gaspard Monge, this in-between remained a space for theoretical speculation and a ground for the development of artistic tools for representation. To make the space operational in a wider sense, it had to be developed and refined.

Important in this development are several figures. I will here only look at one of them, and perhaps the most important: René Descartes. In his writings in the first half of the 17th century, he stressed the ontological status of space, he made space "purer" and he developed mathematical models for how to operate in space. Let me briefly mention some of his claims.

First he was explicit on the necessity to break with the old symbolic and practical discourse of the ancient, the humanistic discourse. For Descartes this discourse had no real access to things; it was blinded by the words, the physical character and symbolic character of things. Descarte's methods want to go down to the purest and most simple foundations. In stead of a humanistic in-between, Descartes wants the pure "in-between".

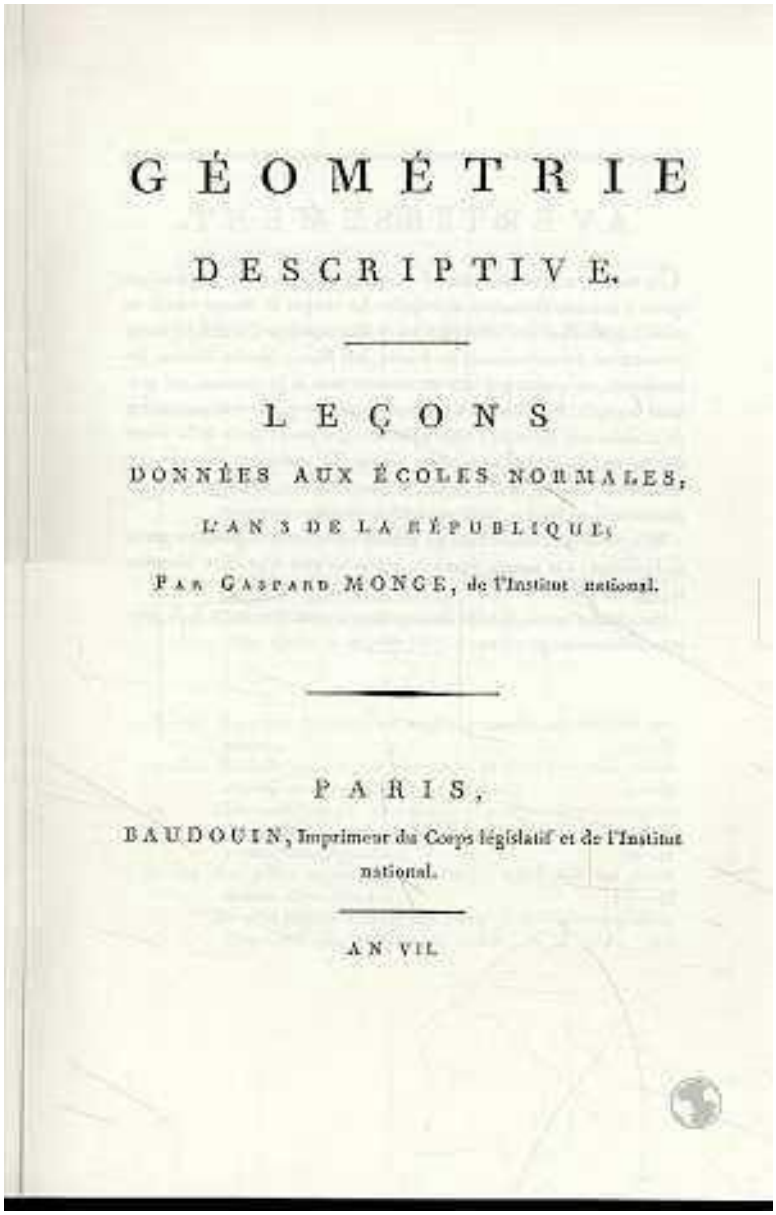
He developed this view in such a radical way that he ended up saying that only extension had ontological status. He thereby dismissed even substance as a category. The thought of substance as tangible was wrong, he claimed. Substance is equivalent with the extensions of the object which again are equivalent with the space in which the thing is occuring. The new physics had only two categories: extension and movement (see *Principa Philosophia*, II, 9ff.).

He also attacked the notion of boarders, which was, as we saw, important in the ancient definition of space. He makes many examples showing that the borders are not reliable. E.g. in *Principia Philosophica* where he states that a man moving in a boat is not moving with respect to the boat but with respect to the land, he is moving. It is only the thought that can make order out of this. Descartes states "that there is no place or no thing in the world which is stable and steady, if we are not able to hold it stable and steady in our thoughts." (II, 13) He emptied the world of things and words, filling it with space and a reason able to order what should be put in it.

The Cartesian co-ordinates are both a representation of the space and a mode to operate in the space. They are not only something in-between, they are in general. They can be used everywhere, on the placement of real and of formal objects. The objects of the in-between can be left out and it is possible to concentrate on the "in-between", the space.

But even in his radicalism, also Descartes had to give the old humanistic discourse some role with respect to space and the organisation of it. His claim was that the existence of mathematical and geometrical figures was a proof for the existence of God (*Meditationes de Prima Philosophia*, 5th med.). In some way, he had turned the ancient world upside down, giving space and its organisation the first, God the second role.

But Descartes made a space operational for thought and mathematical models only. It was Gaspard Monge who first defined a tool for the practical operation in this space. This tool was the so-called *géométrie descriptive*, descriptive geometry, and it was first taught at Ecole Polytechnique in 1794 (figure 7).


GÉOMÉTRIE

DESCRIPTIVE.

LEÇONS

DONNÉES AUX ÉCOLES NORMALES,

L'AN 3 DE LA RÉPUBLIQUE;

PAR GASPARD MONGE, de l'Institut national.

PARIS,

BAUDOUIN, Imprimeur du Corps législatif et de l'Institut national.

AN VII.

Figure 7

Descriptive geometry has been a mandatory subject in all higher engineering education since then. Even as late as in the seventies, we can find the subject on engineering curricula. I think no other course has been so long pursued, with so little change in the content, as descriptive

geometry. The reason for this is that as soon as a debate rose whether the course was important or not, it was always someone to use the argument Monge himself used for the course: Descriptive geometry makes it possible to see in space. A more correct argument would have been: Descriptive geometry made it possible to see in a space that had been developed since the Medieval Ages. There are many stories about the frustration of students with the course and the enthusiasm of the teachers who had learned the method: "Can you see the space now? Aaah, yes NOW I can see it!" (figure 8).

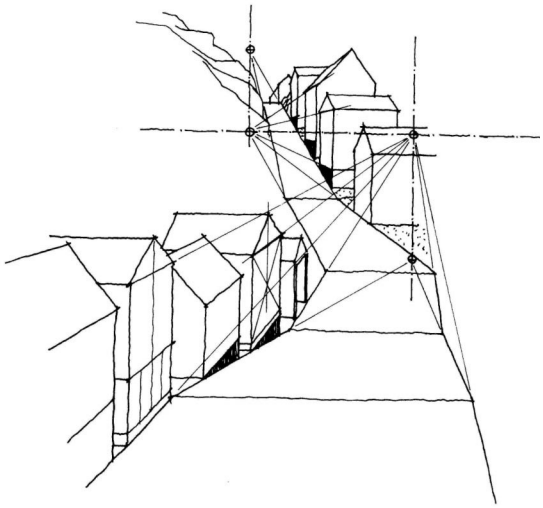
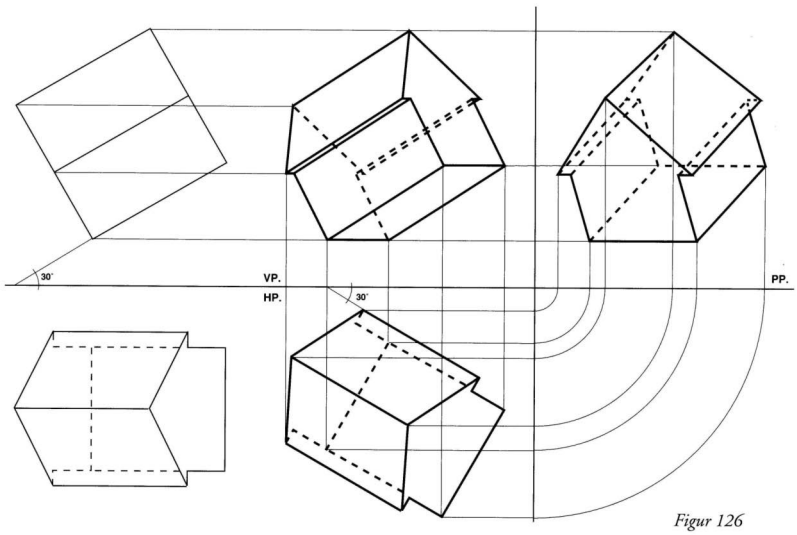


Figure 8

Alberti gave a status to the in-between and developed a tool for organising it, Descartes gave it formal and metaphysical qualities and made it a space to be operated by thought. Monge made a practical tool to see the space. At the same time, and that was perhaps the most important reason for the success of descriptive geometry, it was also a tool for operations in the constructed space. Through descriptive geometry, drawings could be made so that the constructions could be seen and construction drawings could be made. The engineers did not need to see the world as long as they could see the space. So descriptive geometry made it possible to handle objects in space (figure 9), to handle mathematical objects (figure 10) and even to get rid of the old symbolic discourse around geometrical forms; even spheres are only the place they occupy in space (figure 11).



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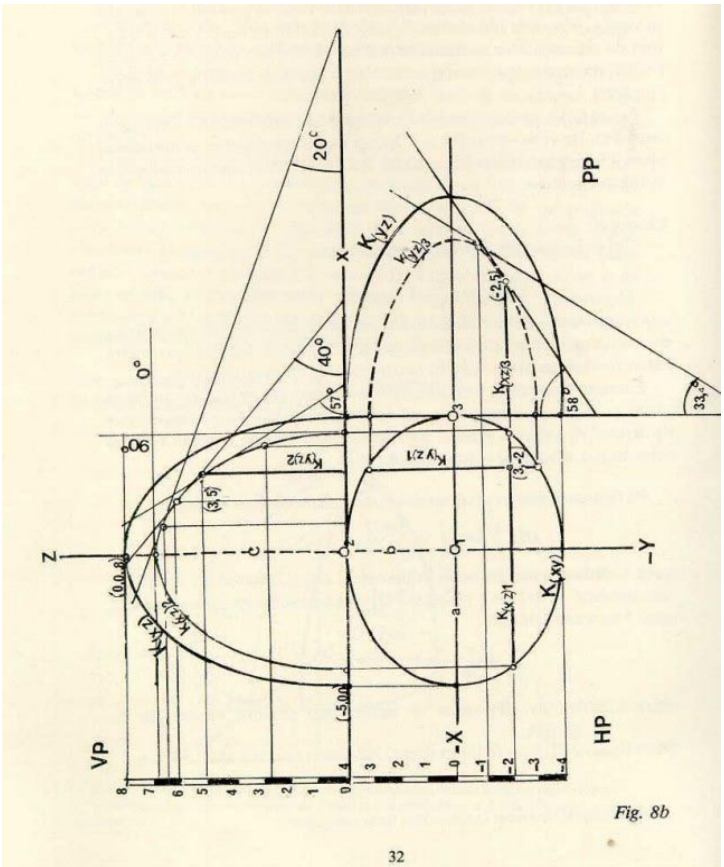

Figure 10

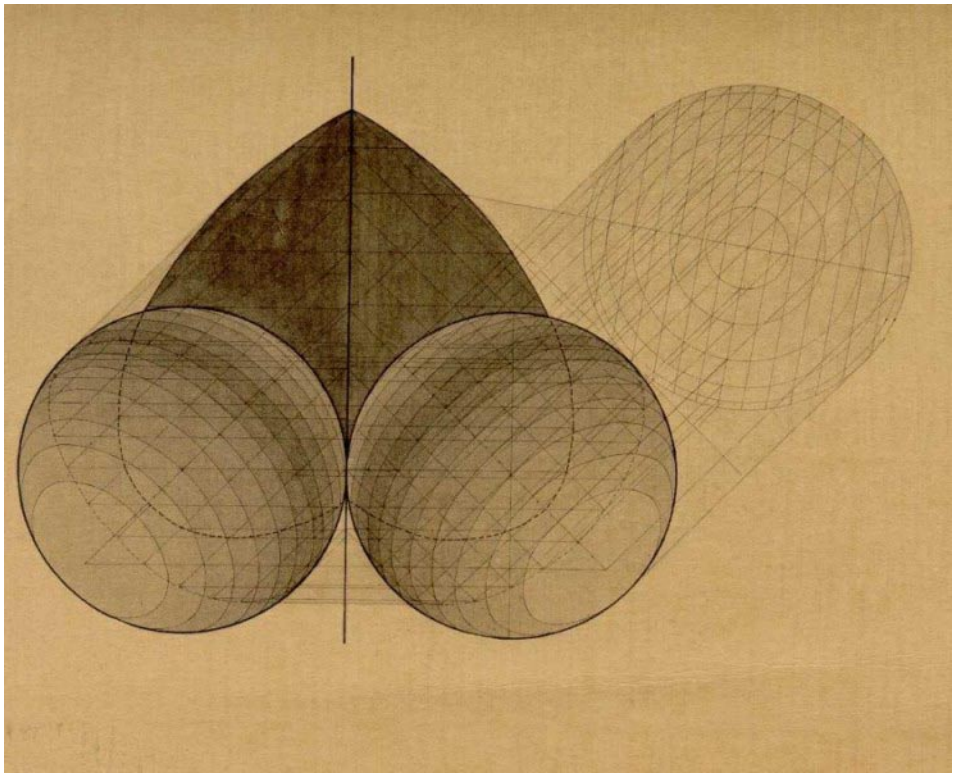

Figure 11

Ludwig Wittgenstein probably taught descriptive geometry when he worked as a teacher in mathematics at the countryside in Austria after the First World War. He also provides a precise formulation that the geometrical figures in general only are stable as long as we see the space they occupy in a uniform way. In the *Philosophical Investigation*, we find a simple drawing of a cube in three dimensions. (figure 12) Wittgenstein shows that what space this figure is occupying, can bee seen in two different ways. To shift from one way of seeing to another means a shift of understanding. “We define it, and see it the way we define it” he said about the cube. More largely spoken, Wittgenstein would say that it means a shift of language games to see it differently. The space constructed by Alberti, Descartes and Monge is itself a discourse.

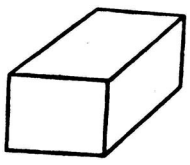

Figure 12

I come to my final remarks: We could hear a similar story about the construction of a different ontology of space: Most constructions also construct a counter-construction. The making of linear space almost calls for a non-linear space. The ontology of space opens for both the ordered and the disordered. The history of space up until descriptive geometry parallels the history of non-Euclidian geometry. Monge made the framework of engineering practice. It implied a differentiation between civil engineering and architecture and art. So I will finish with a challenge to science and technology studies as well as to constructivism: Do not only regard the construction in the making, but also the counter-construction. Instead of focusing on the construction and the construction process, we should see the process as a process of differentiation and of ordering and disordering.