“*di varii instrumenti per misurare con la vista*” [“on Various Instruments to Measure with Sight”]. Notes on the Architectural and Urban Survey in the Renaissance

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Since ancient times, the main cultures have used methods of measurement, even refined ones, for the study of the territory and for the marking and construction of important works. However, between the 15th and 16th centuries the codification and diffusion of instruments and methods expressly designed for the survey of cities and territory rise. It is a period of cultural and scientific development, as well as of transformation of the methods of knowledge transmission, also thanks to the birth and diffusion of large printing houses. In general, treatises combine rational knowledge with operational and functional applications, putting together theoretical, technical and practical interests. It is precisely thanks to treatises that knowledge spreads outside narrow circles, among a wider educated public [Maestri 2001].
In 1545, with the printing in Italian of the *Elements of Euclid*, published in Venice by Niccolò Tartaglia, Geometry becomes the scientific reference for the study of reality and consequently the basis for any initiative of Nature’s domain. In particular, the concept of “measure” plays a central role as a vehicle for certain knowledge, management and transformation of the world. Consequently, measuring instruments become pivotal as devices for a scientific “quantization”. In this sense, the work from which this paper derives its title is a volume by Giorgio Vasari il Giovane dated 1600 consisting of the collection of “cards” relating to surveying instruments and methods, deduced from 29 treaties; it is contemporary to the reorganization of the so-called “Stanzino delle matematiche” [“Mathematical Room”], destined to house the scientific instruments collected by Cosimo I and his successors: in fact, a real *ante litteram* “encyclopaedia” on surveying [1].

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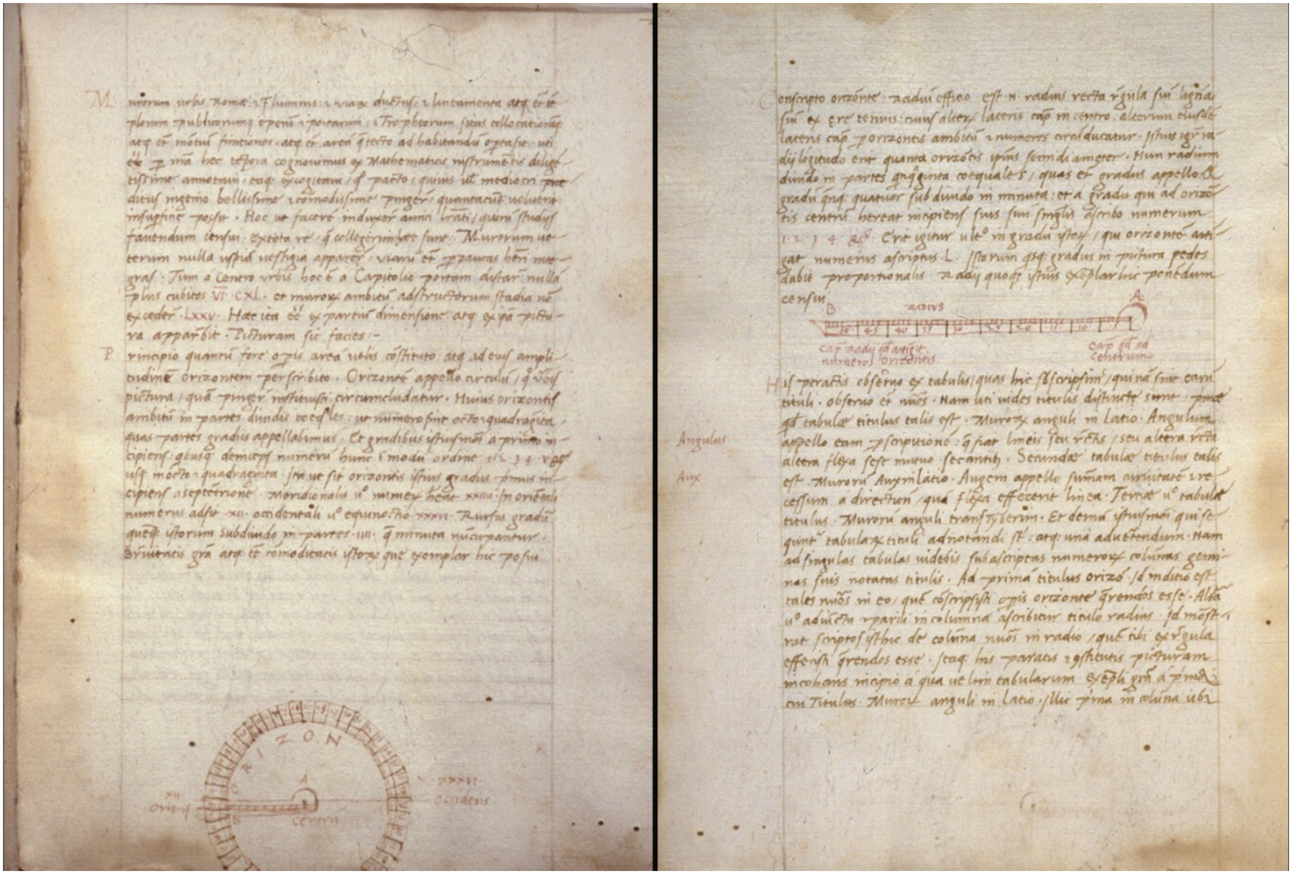
Fig. 1. L.B. Alberti, drawing of the horizon and radius in the Descriptio Urbis Romae (© Bodleian Library, MS. Canon. 172, fol. 233 r-v).



Historical methods and instruments for indirect surveying

With regard to indirect surveying of distances and heights, targeting the point to be measured from one or more station points, the treatises describe the instruments and their use with precision [Centofanti 2001; Centofanti, Brusaporci 2013]. For the most part the instruments can be ascribed to two types, based on the methodology underlying their use.

First of all, there are the tools that, by sighting the point to be measured, come to define similar triangles that allow to calculate distances applying the so-called "rule of three" – according to the diction spread by Fibonacci in his Liber abaci at the beginning of the thirteenth century –, i.e. proportions between the sides of similar triangles, so you don't have to resort to trigonometry, which is more complex to use in practice. This is how the geometric square, the Latin radio, the Jacob's staff, to name but a few instruments, work. Obviously, these tools can also be used to define alignments. Among the first examples, the one described in 1346 by Dominicus de Clavasio in his *Practica geometriae*.

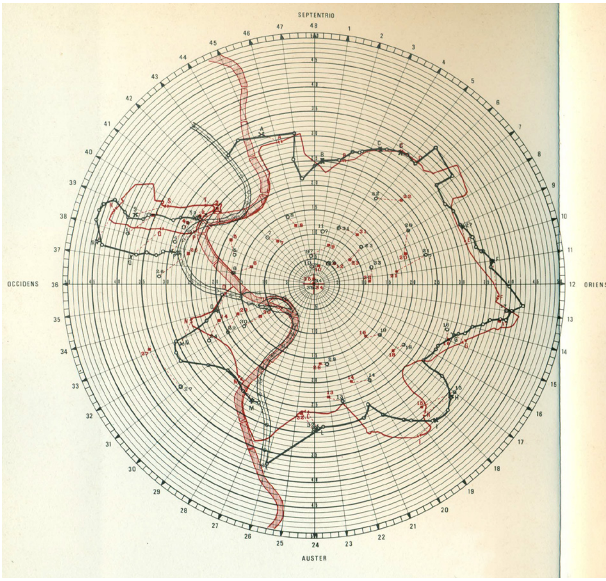
The second type, substantially derived from the astrolabe and based on the use of the magnetic needle (compass), allows you to record the directions of the visual rays with respect to the wind rose, i.e. to the north. The principle is expressly formulated by Alberti in his *Ludi mathematici* (1450-1452), where he describes a horizontal circle with a diameter equal to one arm, divided into 48 degrees, each composed of 4 minutes. It is evident that the act of drawing is intrinsically related to that of measurement, being the result of graphic processes. This is manifest in the use of the so-called "compass with the magnet", as it is called by Raffaello in his letter to Pope Leone X (or substantially the "horizon" of Alberti, or the "surveying compass", or the "Praetorius' Mensula", which differ for some details), which allows to trace the orientation of the roads directly on the map, in reduced length according to the scale.

The representation of Rome by Leon Battista Alberti

Among the methods to "measure with sight", we cannot help but linger on "intersection forward" used by Alberti for the survey of Rome in his *Descriptio Urbis Romae* (1443) (fig. 1). Based on a graphical method, the map of the city is returned through a table of polar coordinates that identify the position of the monuments in relation to the Campidoglio (fig. 2) [Vagnetti 1968]. If in the *Descriptio Urbis Romae*, Alberti explains how to return the coordinates graphically, it is in the *Ludi mathematici* that he illustrates the method of "intersection forward". But in the surveying of Rome, the question of what further station points might have been used remains open (fig. 3).
Luigi Vagnetti, commenting the *Descriptio Urbis Romae* in the light of the *Ludi mathematici*, writes «Alberti does not mention the need for direct measurement between the two station points, which is however implicit in the procedure» [Vagnetti 1968, p. 40], but if in all probability Alberti was aware of the question, however, this issue might not be so "implicit" because, as Vagnetti himself observes "Albertian coordinates do not provide any actual measurements, reproducible in any ratio; they give angular values that can be quickly transported on the drawing sheet by means of a goniometer equal to the one used by Alberti, but radial values that are only fractions of a hypothetical semi-diameter of an horizon large at will; therefore the metric scale of the drawing is dependent solely on the graphic width

Fig. 2. Panorama of Rome from the roof of Musei Capitolini. The Campidoglio is used by Alberti as the reference for the graphic restitution of monuments position listed in the Descriptio Urbis Romae (photo by the author).

Fig. 3. L. Vagnetti, graphical reconstruction of Rome map drawn according to the coordinates presented in the Descriptio Urbis Romae in relation to the real position of the monuments (Vagnetti 1968, p. 43).



of the horizon" [p. 53]. What has been observed is tacit in the use of similar triangles, where, if the length of the base is chosen at will, the result returns in proportion, but on a different scale. The considerations that the monuments identified in the *Descriptio Urbis Romae* are surveyed with great precision – according to the method and the age –, but also that the overall plant omits many other elements of great importance, strengthen the idea that the author's intentions are not to provide a detailed map of Rome for practical city management, but rather to demonstrate the usefulness and simplicity of a method.
Alberti works in an analytical way, so as to be able to describe the map of the city through a coordinate system, and not to have to insert a drawing in his manuscript, which would have entailed reproduction difficulties for copyists. In this way it elevates the operation of tracing signs to an intellectual act of geometric knowledge and physical representation [Carpo, Furlan 2005]. The presence of one of Alberti's rare drawings in the *Descriptio Urbis Romae* – with the representation of the "horizon" and of the "radius" – is an element of particular interest, worthy of specific study and reflection. Mario Carpo writes "albertian renunciation of the illustration of the text […] is a direct and paradoxical consequence of the new importance and the new function that Alberti gives to the image. New forms of knowledge, new techniques and new fields of knowledge require figural representations, experimentation, and verification through the image. The image is now the irreplaceable vector for the representation of figuratively quantitatively precise data, which, however, cannot be transmitted as precisely in graphic format. Alberti can already create, but still cannot communicate modern images" (p. 22). Therefore, remembering how in *De re aedificatoria* the intention to express "solis verbis" is expressly stated, the fact that Alberti, contrary to his mistrust of the depictions, inserted in the *Descriptio Urbis Romae* the drawing of the "horizon" (fig. 1), instrument to measure but also to redraw, representation in any case accompanied by a detailed textual description, could be interpreted as a choice dictated by pragmatic reasons: the text is intended for a wider audience than that of scholars alone. And in fact Alberti, in the opening of *Descriptio Urbis Romae*, writes: "I have devised a method, by which anyone *with normal intelligence* will be able to graphically represent the above mentioned things in the most suitable and convenient way" [Vagnetti 1968, p. 61]. This hypothesis would go hand in hand with the spread of knowledge and techniques during the Renaissance, also remembering how Alberti, while usually writes in Latin, do not disdain the vulgar, writing his *De Pictura*, or *Sulla Pittura* (1435) in both languages. Even if the *Descriptio Urbis Romae* is written only in Latin, there is no doubt that the work aims at a wide diffusion.

The eidotypes of Leonardo da Vinci

It is considered interesting to comment on Leonardo da Vinci's surveys of the fortresses of Cesena and Urbino, and of the city of Imola (1502), of which one is fortunate that we have the notes of the surveying campaign [Docci 1987]. In the eidotypes of Cesena, limited only to the fortified perimeter, Leonardo traces on the sheet the sections of the walls oriented according to the north and notes, adjacent to each line, the measurement of its length and orientation in relation to the wind rose, evidently using a Dioptra with compass (fig. 4).
The surveying sketches concerning Imola present the road network and the perimeter of the town (fig. 5). The road axes are generally traced in their relative correct orientation, the lines of the roads are accompanied by a note of the length, but the measure does not correspond, in scale, to the real length. In particular, the orientation with respect to the wind rose is not indicated. Moreover, even if the eidotypes show the length of the roads, the Via Emilia and the external perimeter of the built-up area take exception (except for a few small sections); but the same Via Emilia, traced in a straight line, i.e. ignoring the flexure in the eastern part, is used as a reference to divide the city into the districts on the basis of which the survey is conducted, becoming the main reference.
Also in consideration of the fact that it is difficult to imagine how the so accurate and well known Imola map can be derived from these sketches (fig. 6) – unless we take into consideration the possibility, not entirely to be excluded, that Leonardo's drawings are based on previous maps [Mancini 1979] –, hypothetically speaking, it could be assumed that the survey under analysis was developed in two phases: a first phase, whose drawings would have been lost, could have been dedicated to the survey of the Via Emilia and the external perimeter, with a methodology similar to the one used for the survey of Cesena, i.e. making a polygonal including the measurement of direc-

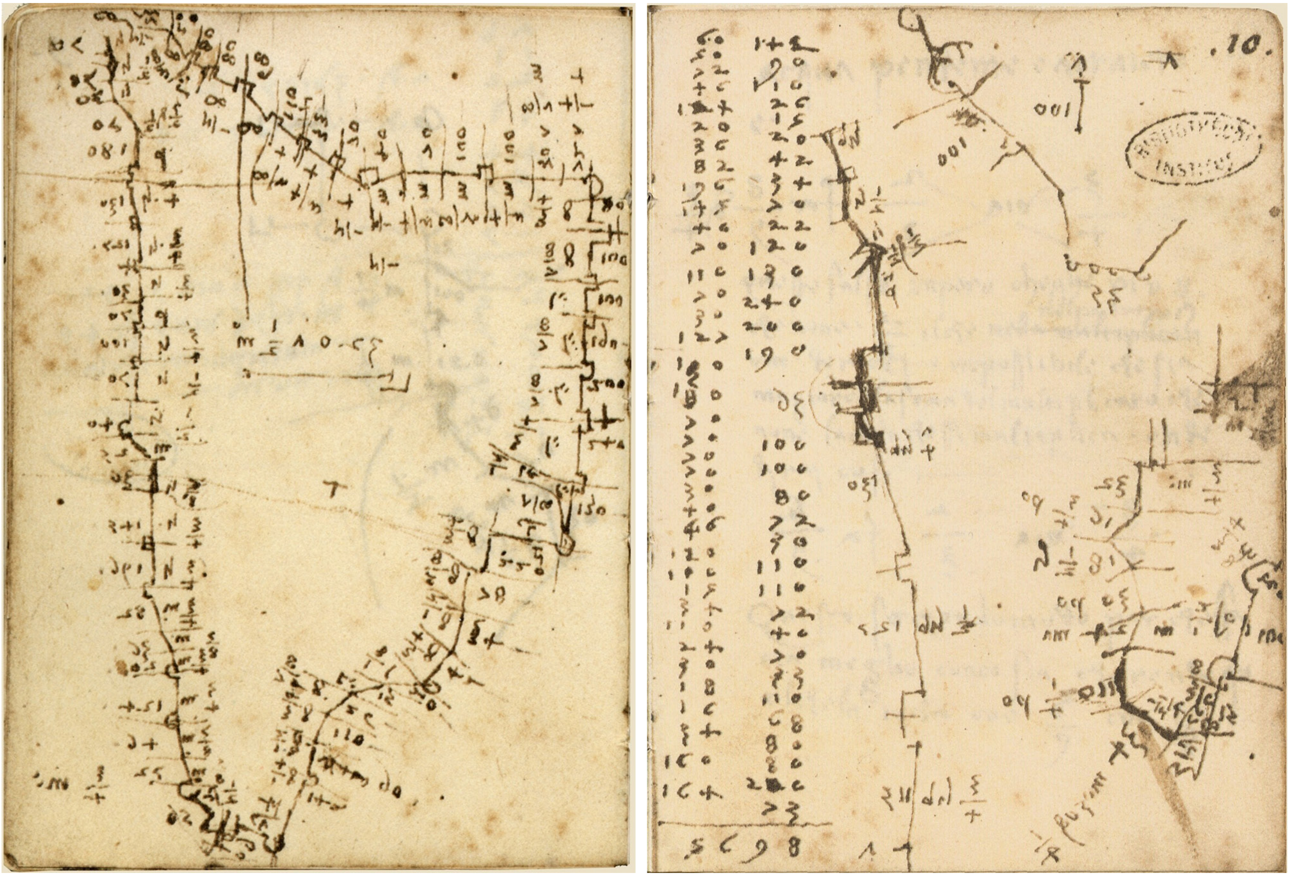


Fig. 4. Leonardo Da Vinci, surveying eidotypes of the Cesena fortification (Manoscritto L, f. 9v e f. 10r).

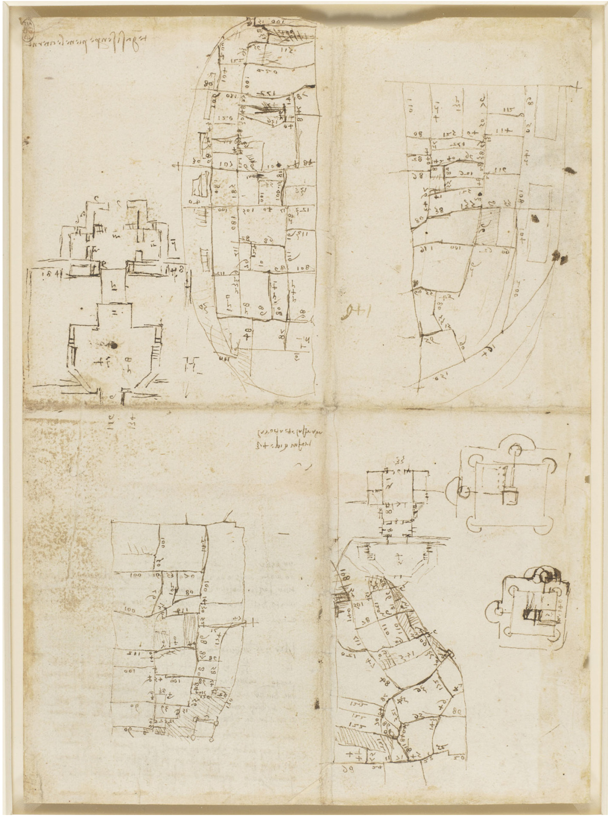


Fig. 5. Leonardo Da Vinci, sketches of the roads of Imola (Royal Collection Trust / © Her Majesty Queen Elizabeth II 2019, RCIN 912686).

tions; a second phase, dedicated to the survey of the internal roads, would have been carried out at a later stage, using a traditional Dioptra of Heron without magnetic compass, or a Geometric square with moving sides (also called "squadra zoppa") able to trace the relative orientation between roads. If accepted this hypothesis, the small crosses drawn by Leonardo at the external entrance of the current via Emilia (east side), via Appia and via Bixio could indicate points of station referred to the rose wind, by means of a compass, connecting the surveys of the external perimeter of the built-up area and the internal road network (fig. 7). The irregularity of the rectilinear part of the via Emilia, in the west area in the famous map, could be the result of the need to compensate for measurement errors between the external perimeter and the internal roads during the restitution phase, consequently to the use of different surveying methodologies. And that there was some uncertainty in the measurement phase is evident from the fact that the notes present at the same time a sketch of the entire northern part of the city – with various corrections for the northeast area –, and a second sketch of the northeast part, the one with the real flexure of the via Emilia.

The *Geometria prattica*: a treatise that becomes an "handbook"

In 1599 the treatise *Geometria prattica* was published; it was written by the Venetian Giovanni Pomodoro, scholar of vast experience, probably involved in that great project of transformation that the Serenissima, as new continental power, was consolidating (fig. 8).
The treatise is a posthumous publication of an unfinished work, consisting of the tables drawn by Pomodoro, with the subsequent addition of comments by Scala [Brusaporci 2016]. The work configures with a particular practical and operative point of view, also thanks to the graphic quality and expressive clarity of Pomodoro's drawings, and in particular those relating to methods and tools for surveying (figs. 9-11). And indeed in this, in all probability, lies the fortune and modernity of the work: it configures as an "handbook" more than an exhaustive "treatise". The *Geometria prattica* is constantly mentioned above all in relation to the use of the surveyor cross, an instrument to which numerous tables are dedicated. However, many other instruments are represented in the treatise,

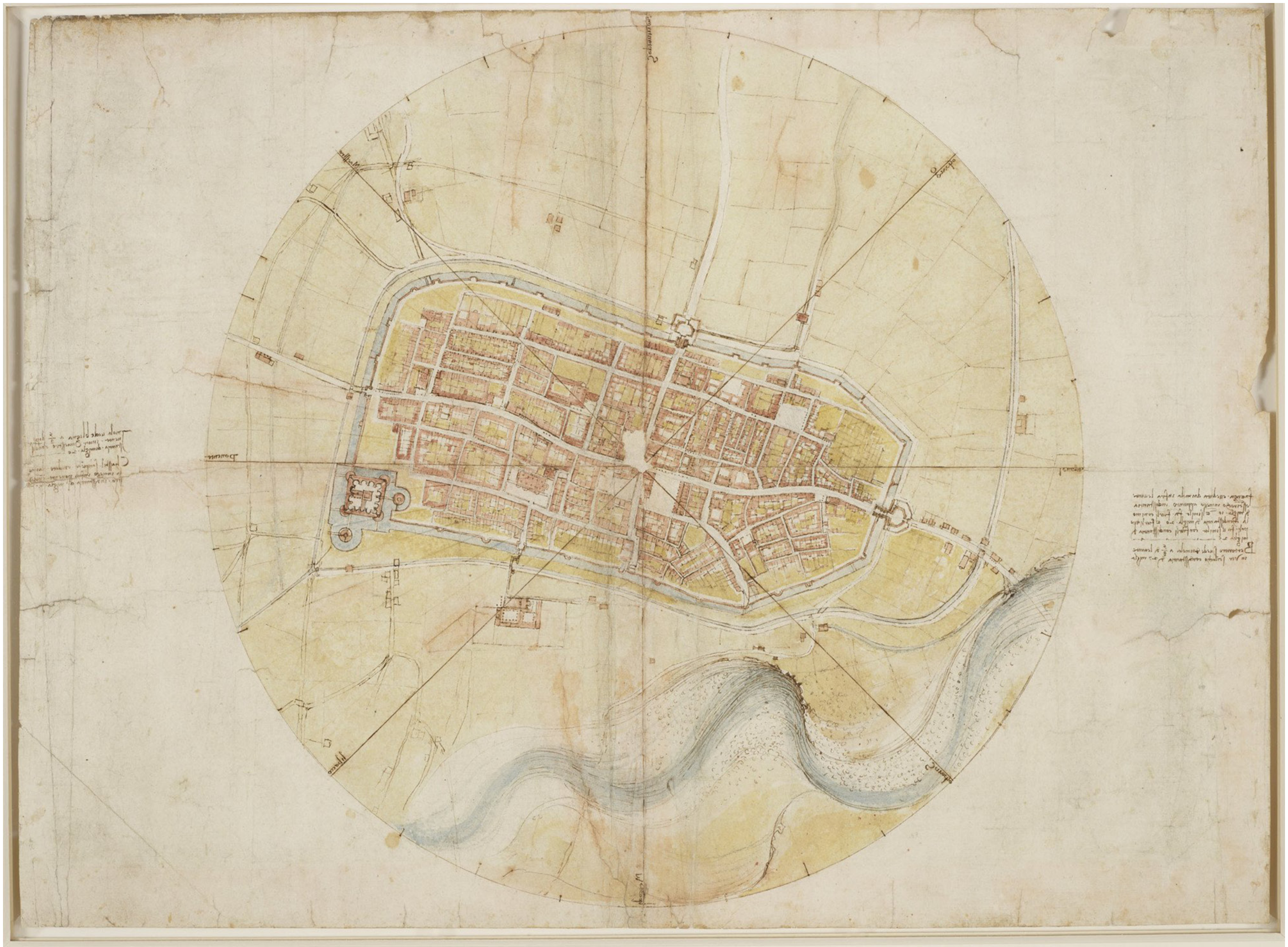


Fig. 6. Leonardo Da Vinci, Map of Imola (Royal Collection Trust / © Her Majesty Queen Elizabeth II 2019, RCIN 912284).

Fig. 7. Overlapping between the sketch of the northern area (cfr. fig. 5) and the map (cfr. Fig. 6) of Imola by Leonardo Da Vinci. Highlighted: 1) the roads inside the built-up area with the annotation of the length; 2) the external perimeter without measures; 3) the Via Emilia traced with a linear course, without taking into account the real irregularities and without measuring the length of its sections ; 4) one of the crosses drawn at the external entrance of some roads, hypothetical station points, perhaps to connect different surveying campaigns.

such as the "squadra zoppa" and the geometric square with quadrant.
The drawing of the geometric square, at the Table I (fig. 8), is particularly accurate and with important dimensions with respect to the whole table: the represented instrument is refined, in all respects comparable – if not more elaborate – to the ones of Walther Hermann Ryff (1548), Giovanni Francesco Peverone (1558) or Cosimo Bartoli (1564). Considering the importance that Pomodoro gives to this representation, as well as the fact that the geometric square allows the calculation of distances using proportions between similar triangles – that is according to the method used and systematically explained by Pomodoro – it is believed that it cannot be excluded that the *Geometria prattica* could have foreseen other tables, not realized due to the premature death of the author, precisely related to the use of the geometric square. And the characteristic of an "unfinished" work appears from various drawings, partially incomplete. This is only a hypothesis, but in this case the complete work would have taken on a different character, so that it could not be counted substantially as a "treatise on the surveyor cross" and taken on a greater breath.

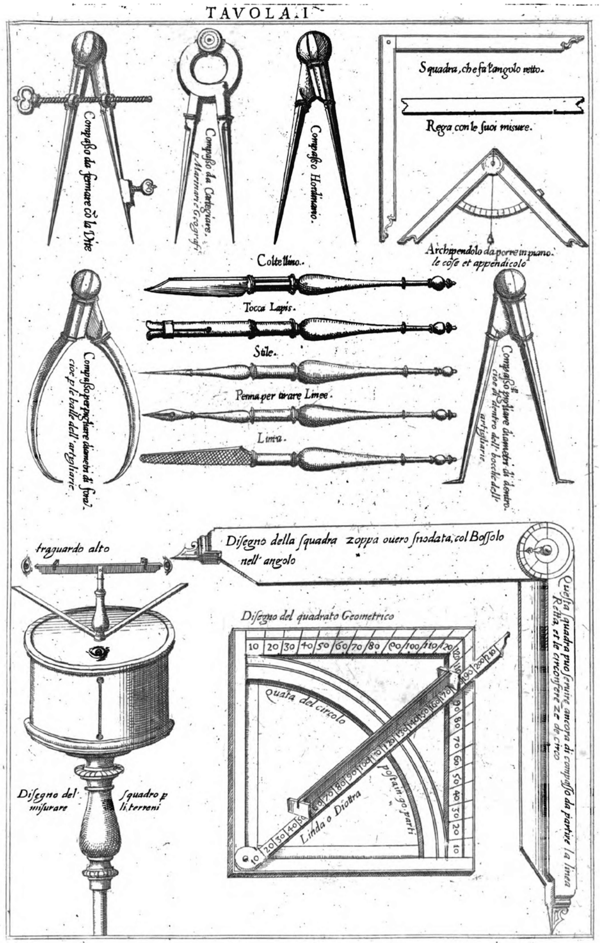
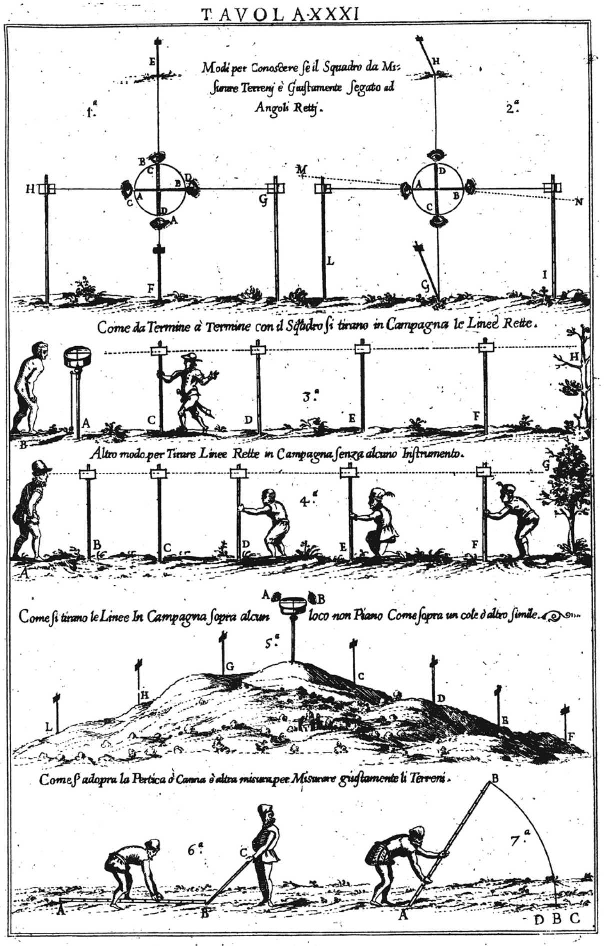


Fig. 8. G. Pomodoro, Geometria prattica, Tav. I. Representation of drawing and surveying tools. In particular we can see the surveyor cross, the geometric square and the square with hinged sides.



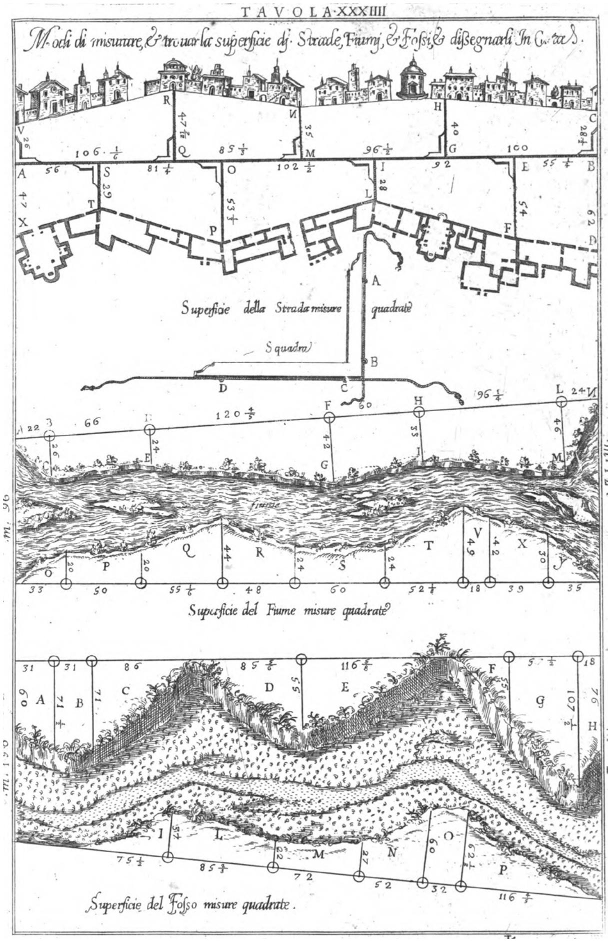


Fig. 9. G. Pomodoro, Geometria prattica, Tav. XXXI. Illustration of the use of the surveyor cross for land survey.

Fig. 10. G. Pomodoro, Geometria prattica, Tav. XXXIIII. Use of the square and the surveyor cross to survey roads, rivers, and territories.

Fig. 11. G. Pomodoro, Geometria prattica, Tav. XXXIX. Example of the use of the square to measure and drawn a territory.

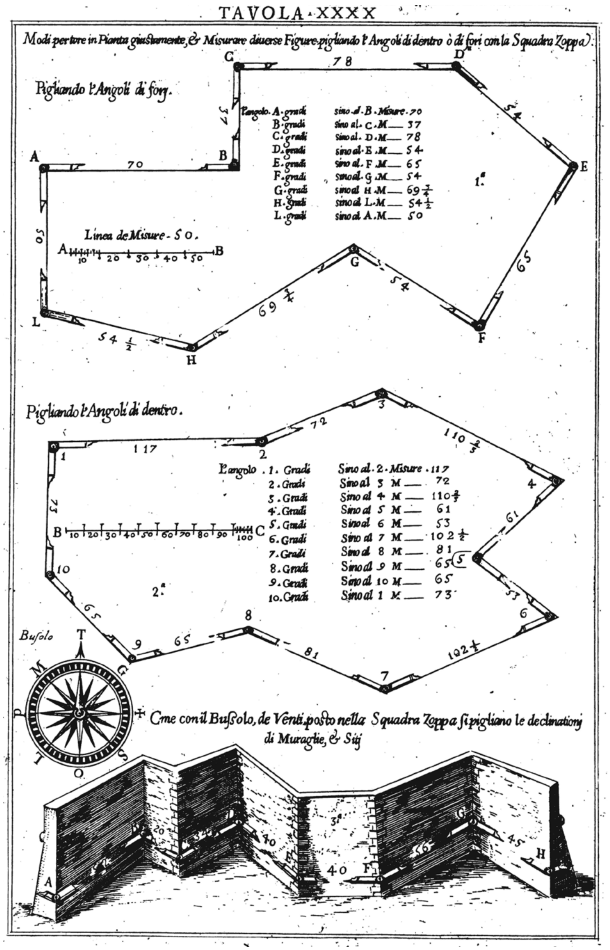


Fig. 12. G. Pomodoro, Geometria prattica, Tav. XXXX. Realization of surveying polygonal using of the square with hinged sides.

The Table XXXX (fig. 12) describes the "squadra zoppa" i.e. a square with hinged sides with goniometer and magnetic compass, to measure internal and external angles between the walls of buildings. The tool is of particular interest as it allows you to trace polygonals accompanied by field notes, where the measurement of the length of the sides is accompanied by the one of the angle formed by the segments, and at the same time by their orientation with respect to the wind rose. It is an instrument of simple use, therefore potentially very effective also compared to the Dioptra of Heron [2].
Given an overall structure of the *Geometria prattica* marked by a first theoretical part and an applicative second one, the treatise of Pomodoro offers to his contemporaries a work in keeping with the needs of clients, useful for practical administrative requirements, and simple in format and content. The rigour that in any case underpins Pomodoro's writing shows the ambition to offer everyone the discipline of measure. It is a context where academies flourish, fostering the dissemination of knowledge, and they become the centre of intellectual life. The *Geometria prattica* works in consonance with this context, in fact offering a volume accessible to many, in a certain sense making a "vulgarization" of knowledge [3]. This in line with the spirit of the Counter-Reformation "capable of welding the culture of the dominant classes to that of the subordinate classes in order to achieve the process of more complete ideological homogenization that the Church had carried out up to then" [Cozzi 1987, p. 25].
In a certain sense, the *Geometria prattica* accomplishes an ideal path of translation and diffusion of knowledge, which moves from Alberti's textual dimension to the visual power of Pomodoro's tables.

Conclusions

With the turn of the 19th century and the development of the mechanical industry, the creation and diffusion of precision instruments for indirect surveying have supplanted the use of traditional instruments, with the consequent recovery of the use of trigonometry.
Also because of the rise of a specific historical attention to the ancient instrumentation that by now was finding its place in the museum, a series of writings dedicated to the history of surveying instruments and methodologies spread. These writings present different declensions, highlighting, depending on the case, the characteristics of the instruments, their historical-critical framework, the methods used, the types and characteristics of the restitution graphs [Lyons 1927; Boffito 1929; Kiely 1947; Vagnetti 1970; Docci, Maestri 1993; Stroffolino 1999; Lindgren 2007; Cigola 2016]. In particular, Edmond R. Kiely correlates the historical aspect with that of applied teaching, based on the conviction that "It is scarcely controvertible that an engineering education which does not include the history of the particular branch of engineering being pursued is incomplete" [Kiely 1947, p. ix].
Similarly, the study of historical methods and instruments of surveying and the culture behind them have to be an integral part of the training of scholars and professionals who aims to dedicate themselves to this field of knowledge, so as to be able to operate with critical awareness in the study of historical works and documents, in the drafting and analysis of surveying representative models, where the critical capacity of the surveyor plays a central role.

Notes

[1] Giorgio Vasari il Giovane. (1996). *Raccolto fatto dal Cav.re Giorgio Vasari: di varii instrumenti per misurare con la vista*. Reproduction of the edition of 1600, edited by F. Camerota. Firenze: Giunti, 1996.

[2] In this regard, in the first table of the treatise where the main instruments of surveying are represented, there is not the Praetorius' Mensula: considering it unlikely that Pomodoro, a professional in the field of surveying, would ignore its existence, perhaps the author wanted to suggest the "squadra zoppa" as an easiest tool to use.

[3] An indirect evidence of this phenomenon of making techniques within the reach of many, is the "aristocratic" attitude that, for example, is evident from a passage in the treaty Geometria (1597) of Fonticulano: "Because if I wanted to describe the practice of swarms, which is so easy, that every mediocre genius could have exercised it, I would have done the professors wrong because they never wanted so much to facilitate the path to the ignorant [...] who have nothing but that bare practice which they themselves do not know whether it is good or bad, and they want to prove that they know, and presumptuously to be a professor": Ieronimo Pico Fonticulano. (1597). *Geometria*. Anastatic reproduction of the edition of 1597, edited by D. Maestri. L'Aquila: Fondazione Cassa di Risparmio della Provincia dell'Aquila, libro VII, p. 258, q. 2.

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