

FRANCESCO DI GIORGIO ON MECHANICS: A QUATTROCENTO LESSON ON THE TRANSMISSION OF KNOWLEDGE

This article discusses the illustrations and descriptions of machines in the two main theoretical writings of Francesco di Giorgio, dating from the 1480s and 1490s, respectively. First, the singular characteristics of the two writings are highlighted, enabling us to characterize the earlier work as a “handbook” and the later one as a “treatise”. Then a small selection of machines is examined, with special regard for the use of technical terminology in the volgare text and for the representational methods of the individual drawings. This offers new insights into Francesco di Giorgio’s approach in representing three-dimensional machines in drawings and underscores his eminent role among Quattrocento engineers. The article further contributes to our understanding of Quattrocento architectural theory by offering English translations of all the volgare passages quoted.

The Sienese artist and architect Francesco di Giorgio (1439-1501) left us two writings on architecture and mechanics, dating respectively from the 1480s and the 1490s¹. Both are written in the Tuscan *volgare* and exist only in manuscript form. The two works differ significantly in content and form, but both treat architecture in a broad sense, including fortification, civil and religious architecture, and mechanics. I propose to call the earlier writing a “handbook” and to maintain the conventional term “treatise” for the later one². While the handbook deals with technical aspects in great detail – more than half of it being devoted to engineering – and is strongly orientated towards practice, the treatise focuses much more on architecture and fortification and appears to address more directly an erudite readership. Both writings are characterized by their extensive and didactic use of drawings, which was not a feature of the few contemporary architectural writings of Alberti and Filarete. Only in the much later conceived and, more importantly, printed books of the Cinquecento were illustrations used programmatically³. In this essay, after describing the main characteristics of the handbook and the treatise, I shall address a set of mechanical devices and highlight Francesco’s innovative method of communicating mechanical-architectural knowledge⁴.

The handbook exists in the form of two manuscripts – the Saluzzianus 148 (Turin, Bibliote-

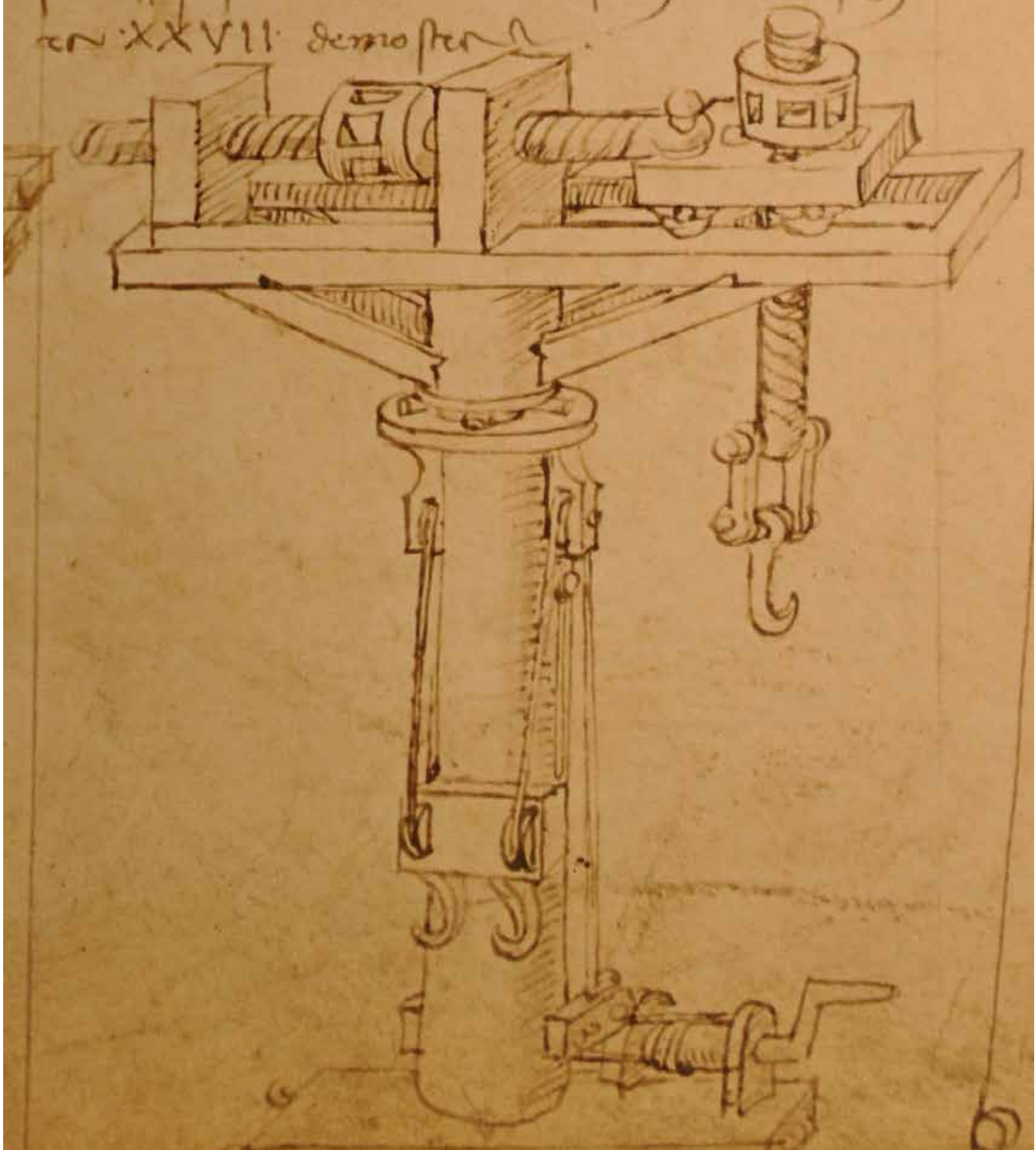
ca Reale) and the Ashburnham 361 (Florence, Biblioteca Medicea Laurenziana) – which are non-autograph copies, composed probably in Francesco’s workshop⁵. They have no table of contents, but one can divide the handbook into chapters, each with different stylistic and rhetorical characteristics⁶. The mechanical sections use rhetorical and structural features from contemporary abacus and geometry manuals that had a long tradition, going back to the twelfth century. These include directly addressing the reader by employing the personal pronoun “*tu*”, the frequent use of the formulas “*Se (per altro modo) [...] alzare/fare [...] vorremo*”, “*(Similmente) Faccisi*” and “*(Si) Anco [...] ordenare/fare*”, as well as connecting the phrases with the conjunction “*e*”⁷. The structure – short paragraphs and case-studies – also derives from these models⁸. Nevertheless, Francesco innovates the approach by strengthening the role of the image: every single paragraph is associated with a specific drawing, while a linking system of numerals (Arabic or Roman), letters or symbols placed at the end of the paragraph is implemented – even if only partially⁹. However, the correct association is clarified mostly by the layout as drawings are usually placed next to the paragraph (in the left or right margin). Traditionally, practical manuals were illustrated, mainly with regard to measuring methods, but not nearly with such continuity and rigor as is done by Francesco¹⁰.

The treatise, preserved in the first part of the Codex Magliabechianus II.I.141 (Florence, Biblioteca Nazionale Centrale), shows greater cohesion in its organization, featuring a prologue with a list of the individual *trattati* (chapters) and a conclusion¹¹. Every chapter has a preface, but the internal structure and layout of the individual chapters varies depending on the topic. Francesco brings together all the mechanical topics in the last chapter, where he proceeds from one general question to the next, explaining each with a small selection of illustrated solutions. Compared to the handbook, the rhetoric of the treatise is more sophisticated and concise, even if Francesco maintains a certain simplicity in his expressions. He again operates with case studies, but these can also be used to infer more general rules or be employed as a starting point to develop similar devices. Francesco suggests in discussing the *tirari* (cranes)¹²:

And with this I shall conclude the part on the lifting machines for building because from [the example of] these ones it is easy to compose others¹³.

Thus, the case studies are characterized as examples representing a much wider range of possible machines¹⁴. Consequently, the treatise features far fewer drawings than the handbook, and the ones present are drawn on a bigger scale. Each page of the mechanical section has its text written in one single large column and is illustrat-

elle due de busto referendosi: e sopra il maspo de
la dentata cuota d'arrollato con questo maspo
per assai facil mente tirar simhorne la fishu
en XXVII. demoster



pagina 23

Fig. 1 Portable mechanical device, from Codex Ashburnham 361, f. 46r (in di Giorgio Martini, *Trattato di architettura... cit.*, f. 46r).

* I would like to thank Caterina Cardamone and Pieter Martens for the fruitful discussion that helped shape this article. My contribution presents aspects of my doctoral thesis (tutor Prof. Bruno Klein, TU Dresden) which is to be concluded soon. One preliminary piece of information: the translations given are meant to facilitate reading but are by no means literal translations of the complex fifteenth-century *volgare*. Major additions to the original wording are evidenced in square brackets, while in parentheses I repeat the original technical term wherever it seems helpful. The original *volgare* text is quoted in the footnotes and is based on Ashburnham 361 or Magliabechianus II.I.141, transcribed following the parameters of F. DI GIORGIO MARTINI, *Trattati di architettura, ingegneria e arte militare*, a cura di C. Maltese, I-II, Milano 1967 (II vol).

¹ Francesco di Giorgio was trained in Siena where he worked as artist and engineer (1460s); later he was employed at the ducal court in Urbino by Federico da Montefeltro and then Guidobaldo da Montefeltro, from 1475 to 1488; in the 1490s he worked in Naples and Siena. See in general: *Francesco di Giorgio architetto*, a cura di F.P. Fiore, M. Tafuri, Milano 1994. Maltese's interpretation of the two writings as two versions of a treatise entitled *Trattato I* and *Trattato II* is now widely accepted, see DI GIORGIO MARTINI, *Trattati... cit.*, I, *Introduzione*. On their dating see also the well-argued chronology in M. MUSSINI, *Francesco di Giorgio e Vitruvio. Le traduzioni del "De Architectura" nei codici Zichy, Spencer 129 e Magliabechiano II.I.141*, Firenze 2003, with extensive discussion on previous critics.

² In this way I intend to distinguish the two writings more clearly. The major differences between them have already been stressed by P.O. LONG, *Picturing the Machine: Francesco di Giorgio and Leonardo da Vinci in the 1490s*, in *Picturing Machines 1400-1700*, edited by W. Lefevre, Cambridge-London 2004, pp. 117-142.

³ Leon Battista Alberti's *De re aedificatoria* was not illustrated. Filarete's *Trattato di architettura* (1460s) does not illustrate systematically every object discussed, and his use of illustrations as enhanced decoration reveals a different attitude towards them. Illustrated editions of Vitruvius from the Cinquecento are those of Fra Giocondo, Cesare Cesariano, and later Daniele Barbaro. Thereafter, Sebastiano Serlio employs illustrations more systematically. For an introduction, see *Paper Palaces. The Rise of the Renaissance Architectural Treatise*, edited by V. Hart, P. Hicks, Yale 1998; A. PAYNE, *The Architectural Treatise in the Italian Renaissance: Architectural Invention, Ornament, and Literary Culture*, Cambridge 1999. On the impact of printing, see M. CARPO, *Architecture in the Age of Printing: Orality, Writing, Typography, and Printed Images in the History of Architectural Theory*, Cambridge 2001. All give a quite general outline of the architectural treatise's 'genre'.

⁴ The descriptions here discussed are to be found in the chapters (as Maltese divides them): "Geometria [...]"; "Leve di ruote e mulini; sorgenti [...]"; "Modi per elevare e condurre acqua [...]"; see DI GIORGIO MARTINI, *Trattati... cit.*, I.

⁵ Thus, they were under his direct control. See also M. MUSSINI, *La trattatistica di Francesco di Giorgio: un problema critico aperto*, in *Francesco di Giorgio architetto... cit.*, pp. 378-399, who suggested (p. 379) that the two manuscripts were produced in the workshop, a hypothesis which I strongly support. In the same article Mussini explains the dating of Codex Ashburnham 361 to ca. 1480-1482 and of Codex Saluzzianus 148 to ca. 1482-1486 (pp. 380, 382).

⁶ The division in chapters is not explicitly given but can be induced from the content. When revising Maltese's division, the handbook can appear more concise and systematic, but the chapters still show different characteristics. In my opinion the handbook is closely connected to Francesco's training and looks like a collection of separate writings rather than a com-

ed with up to three drawings placed in the broad margins or directly above the text column. In connecting the two elements, the linking system is applied, even though there is no real need for it, since little or no confusion might arise in the pairing. Overall, I consider the drawings in both writings as real protagonists alongside the text, rather than just embellishment.

In the handbook, Francesco rarely explains the function of the drawing explicitly, so it may be useful to consider the passage where he laments the inadequacy of the word¹⁵:

As difficult as it may seem to demonstrate everything through drawings, it is equally impossible to express all things by words. That is because in the things there are so many varied elements to be found, fragmented and opposed to one another. Therefore, it is necessary to make models of almost every single object. Considering that to the mind of the architect, many things seem so easy that he is certain to be able to realize them, one learns that when realizing them one might find many deficiencies which are only corrected with difficulty. For my part, not confiding in myself, I have experimented a good share of all the inventions which are to be shown here¹⁶.

As judging neither the drawing nor the word alone would be sufficient to explain complex devices, Francesco stresses the necessity of the model (*modello*), by which he clearly means three-dimensional models. Furthermore, he states that he used models for experiments, which may allow conclusions about the functionality of the device when built full-scale.

Highly suitable for testing out the applicability of his own ideas and concepts, the model is also the most efficient instrument for communicating ideas. The frequent references to *spienza* (experience), *spirimento* (experiment), and similar processes stress the importance Francesco attributes to experiment and autoptic observation¹⁷. This aspect is strengthened further in the introduction to the mechanical section of the treatise,

where he elucidates his unwillingness to make his inventions public:

because I have elaborated all of them with great difficulties, neglecting my own subsistence. Therefore, it does not seem appropriate to me that these should be made public and thereby be annihilated the invention, as the secret is in the detail.

He also states having demonstrated the ownership of inventions occasionally by explaining them in person¹⁸. Given the paramount importance of experimentation through models, Francesco must have asked himself how to incorporate the proofs into his writings. Drawing probably seemed a suitable solution, even if Francesco was conscious of the limitations of drawing in expressing three-dimensionality and could not consider it a perfect equivalent to a model. However, reflecting on the differences between two-dimensional drawings and three-dimensional models, Francesco establishes the limits within which a drawing may be used to fulfill (partially) the function of a model. The drawing becomes a visual proof of the functionality of the device, as is shown by frequently recurring expressions like "as the illustration demonstrates" and similar phrases¹⁹. In both the handbook and the treatise, the interplay of description and drawing of specific devices was necessary to demonstrate the accuracy of his inventions. In the treatise, drawing is additionally dignified as the main tool of the architect: sight being the most noble of all senses – Francesco here takes his argument from Aristotle – the use of drawings acquires a humanistic and philosophical meaning²⁰. The main function does not change, but, thanks to this theoretical enhancement, the drawing becomes more apt to transmit his ideas to the erudite strata of society. Because of its versatility and dignity, drawing is welcomed among every group of architectural enthusiasts.

I shall now compare handbook and treatise by looking at four mechanical devices that are dis-

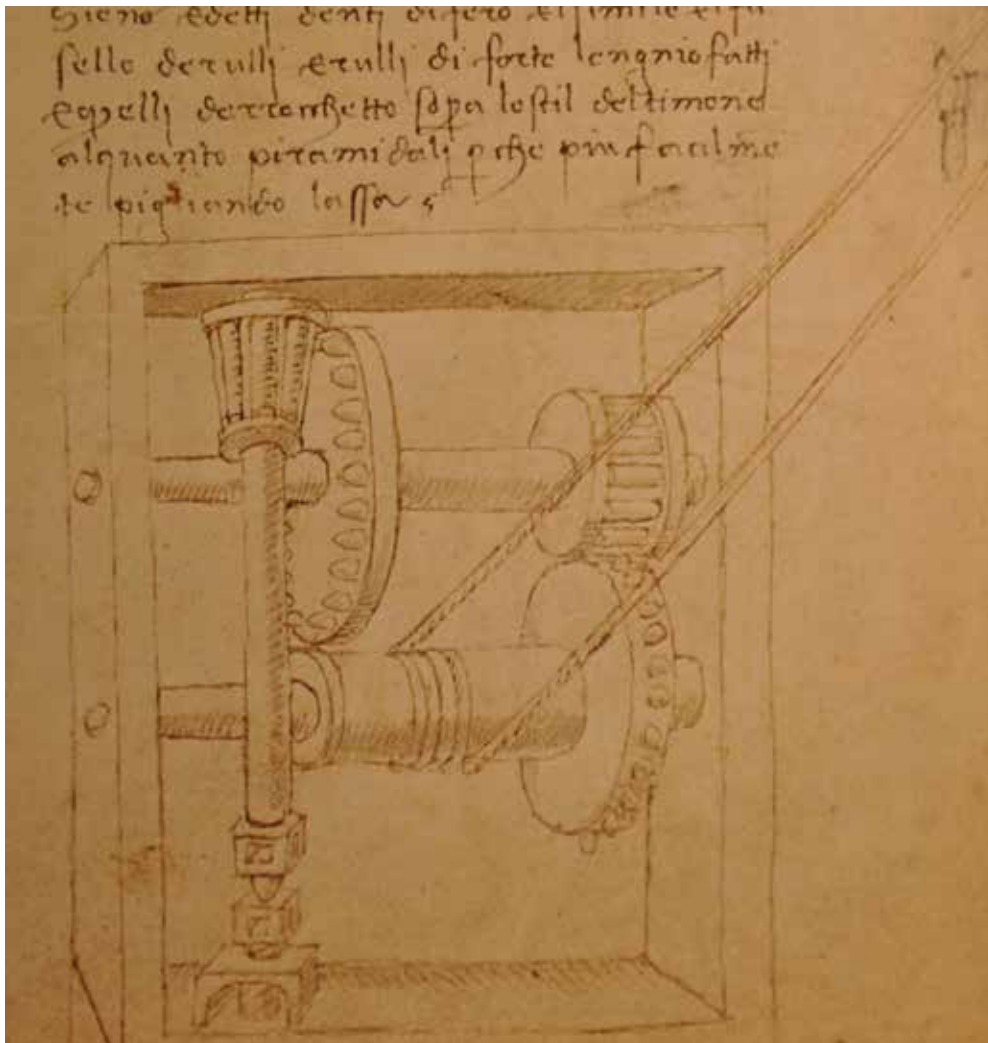


Fig. 2 Mechanical device with rope, from Codex Ashburnham 361, f. 44v (in di Giorgio Martini, *Trattato di architettura... cit.*, f. 44v).

cussed and illustrated in both writings²¹. The catalogs of machines are not identical: in the handbook, the section on winches alone presents thirty different machines²²; the treatise instead features only twenty-one mechanical devices in total, twelve of them related to the construction process. Thus, it turns mechanics into an ancillary discipline for architecture and building practice²³.

The first device is a rope winch described in the handbook as follows:

Another [example:] one should build a frame of timber with a horizontal rod (*traversato fuso*) on which the spur gear (*dentata ruota*) of six feet goes, which is moved by the lantern gear (*rullato rocchetto*) [mounted] on the vertical rod. This [rod] is positioned in equilibrium (*bilicato*) on the screw (*vite*) where the draught animal turns the capstan bars. On the rod above the spur gear is a lantern gear (*rullato rocchetto*) two feet in diameter which connects with the teeth of the spur gear (*dentata ruota*). The latter moves the drum (*curba*) mounted on the same rod as the spur gear. The spur gear (*dentata ruota*) has a diameter of five feet and the drum of two feet. This is shown in figure V. The

teeth are to be made of iron and likewise the shafts (*fusi*) of the lantern gears (*rulli*) of strong wood. The shafts of the lantern gear (*rocchetto*) should be made quite pyramidal in shape because thereby they engage more easily²⁴.

The *armadura* is part of nearly every mechanical device, but is usually called *telaio* or *castello*²⁵; here Francesco additionally specifies it to be made of timber. Furthermore, he indicates the source of power, the *bestia* (draught animal). He gives indications on the measurements – for the *dentata ruota* (spur gear) and *rocchetto* (cage gear) – and on the material, specifying *ferro* (iron) for the *denti* (teeth) of the gearwheel and *forte legno* (resilient timber) for the roll. Thus, Francesco furnishes a thorough description of the instrument. The illustration (fig. 2) (the draught animal is missing) allows for a discussion on a distinct feature of the drawing's convention²⁶. The frame is depicted in axonometric projection, but this is contradicted by the bottom view of the vertical rod, which thus appears to intersect with the lower horizontal rod, making any movement impossible. However, this

pletely uniform book. I suggest that these two manuscripts do not derive from a single model but were instead realized by combining various sources. This would have been possible if they were indeed executed in Francesco's workshop. Without making an intermediate copy, he could have given instructions to use directly the various writings he had composed during his career, as well as those done *ex novo* for the handbook. This would have shortened the whole process and makes it easier to explain certain differences between the two copies. It also explains the necessity of linking text and images, if we imagine Francesco writing a description of machine drawings that already existed in a sketchbook. For further discussion, see my forthcoming doctoral thesis.

⁷ On representations of machines, see *Picturing Machines 1400-1700*, edited by W. Lefèvre, Cambridge-London 2004 (including Pamela O. Long's chapter on Francesco di Giorgio and Leonardo da Vinci). Most useful are *Prima di Leonardo. Cultura delle macchine a Siena nel Rinascimento*, catalogo della mostra (Siena, 9 giugno-30 settembre 1991), a cura di P. Galluzzi, Milano 1991 and P. GALLUZZI, *Gli ingegneri del Rinascimento da Brunelleschi a Leonardo da Vinci*, catalogo della mostra (Firenze, 22 giugno 1996-6 gennaio 1997), Firenze 1996. Some aspects of practical mathematics in E. ULIVI, *Scuole d'abaco e insegnamento della matematica*, in *Il Rinascimento Italiano e l'Europa*, V (*Le scienze*), a cura di A. Clericuzio, G. Ernst, Treviso 2008, pp. 403-420. On the manual tradition, see S.K. VICTOR, *Practical Geometry in the High Middle Ages. Artis cuiuslibet consummatio, and the Pratique de geometrie*, Philadelphia 1979; W. VAN EGMOND, *Practical Mathematics in the Italian Renaissance. A Catalog of Italian Abacus Manuscripts and Printed Books to 1600*, Supplemento agli Atti dell'Istituto e Museo di Storia della Scienza, Firenze 1981 (see p. 16 on codified structure). On drawings in manuals, see E. DE LAURENTIIS, *Il disegno geometrico nei trattati del Quattrocento a Firenze*, "Atti dell'Istituto Veneto di Scienze, Lettere ed Arti", CLIII, 1994-1995, pp. 95-125.

⁸ Galluzzi stresses the intimate connection between the first treatise (our "handbook") and the medieval tradition of knowledge transfer in the *bottega*, see GALLUZZI, *Gli ingegneri... cit.*, p. 44.

⁹ In the handbook's manuscripts, the linking system is nearly always applied; mostly the link is given in the text but missing in the drawing. This might be due to erroneous copying, but Francesco apparently did not correct these deficiencies. Only one section of Ashburnham 361 applies the system as a whole: f. 33r-35r, see F. DI GIORGIO MARTINI, *Trattato di architettura. Il Codice Ashburnham 361 della Biblioteca Medicea Laurenziana di Firenze*, I-II, Firenze 1979. The corresponding section in Saluzzianus 148 has no links in the drawings; further discussion in my thesis.

¹⁰ Two things should be mentioned. The most important is the handbook's intimate relationship with the *Codicetto* (Codex Urb. Lat. 1797 of the Biblioteca Apostolica Vaticana, Rome), which is an autograph sketchbook of Francesco, who used it up to at least the second half of the 1470s, collecting drawings from various sources, see MUSSINI, *La trattatistica... cit.*, pp. 379-380. The codex is online: https://digi.vatlib.it/view/MSS_Urb.lat.1757 (consulted 27 March 2019). Secondly, the handbook's section on geometry is closely related to an anonymous "Trattato di geometria pratica" (edited in ANONIMO FIORENTINO, *Trattato di geometria pratica: dal Codice L.IV.18 (sec. 15) della Biblioteca Comunale di Siena*, a cura di A. Simi, Siena 1993). A hint to this relation was given in F. DI GIORGIO MARTINI, *La pratica di geometria dal Codice Ashburnham 361 della Biblioteca Medicea Laurenziana di Firenze*, a cura di G. Arrighi, Firenze, 1970, pp. 2-3. After a detailed comparison of the two works, inspired by Arrighi's hint, I suggested in the original manuscript of this article (2016) that the two works must have had a common model. Meanwhile, Angeliki Pollali claimed the close relationship with the Codex L.IV.18 as her own discovery, though without mentioning Arrighi's suggestion, see A. POLLALI, *Design Method and Mathematics in Francesco di Giorgio's Trattati*, in *Visual Culture and Mathematics in the Early Modern Period*, edited by I. Alexander-Skipnes, New York-London 2017, pp. 32-51. Arrighi's hint has been mostly overlooked, perhaps because Galluzzi did not mention it when discussing geometry, see GALLUZZI, *Gli ingegneri... cit.*, p. 6.

¹¹ The treatise in Codex Magliabechianus II.I.141 dates from 1496-1500 (MUSSINI, *La trattatistica...* cit., pp. 386-388); the additional translation of Vitruvius' *Ten Books on Architecture* is probably earlier. See MUSSINI, *Francesco di Giorgio...* cit., chapter 3. The Codex S.IV.4 (Siena, Biblioteca Comunale degli Intronati), not discussed here, has hardly any drawings and dates to 1496-1497 (MUSSINI, *La trattatistica...* cit., p. 385). None of them is autograph. Maltese thinks that the fourth manuscript pertains to a different, earlier phase, see DI GIORGIO MARTINI, *Trattati...* cit., I, pp. XLVIII-LI, p. LVI.

¹² Describing the *argani* (cranes), Francesco explains different positions of a roller and relative advantages, see DI GIORGIO MARTINI, *Trattati...* cit., II, p. 496. Francesco continuously employs the term *argano*, which translates as winch, as pars pro toto to indicate the crane. Long thinks Francesco "suggests that readers will be able to read about one kind of mill [...] and then discover other types", see LONG, *Picturing the Machine...* cit., p. 128. Her quotation ("delli altri simili da li lettori possono essere trovati") is contained only in Codex S.IV.4 (see note 11), so I think it might serve only as confirmation of what is expressed in the Magliabechianus II.I.141. Galluzzi, too, notes the treatise's essentiality and presentation of common principles: "Francesco veniva così distinguendosi dalla tradizione consolidata nelle botteghe di affrontare ogni questione tecnica e ogni dispositivo meccanico come un caso a sé stante", P. GALLUZZI, *Macchine senesi: ricerca antiquaria, spirito di innovazione e cultura del territorio*, in *Prima di Leonardo...* cit., p. 38.

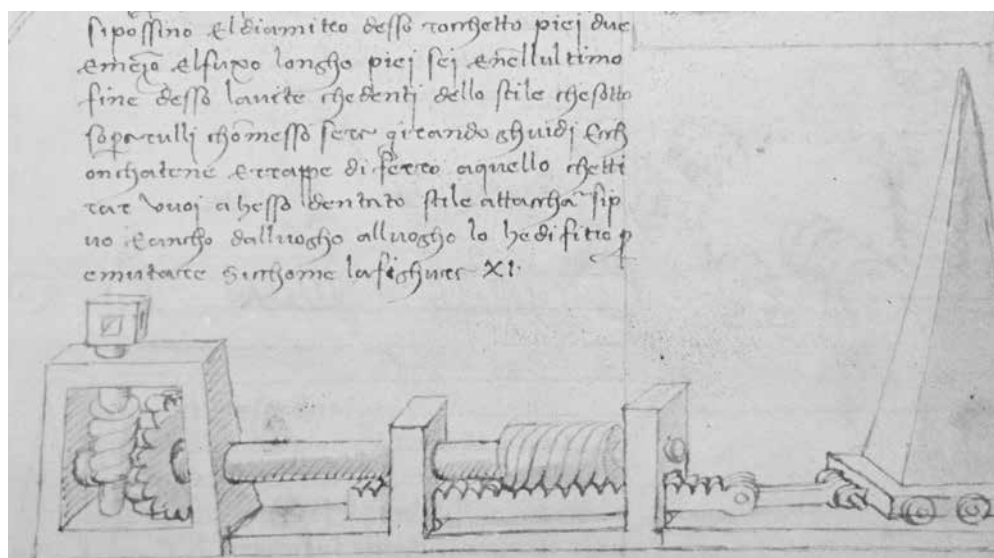
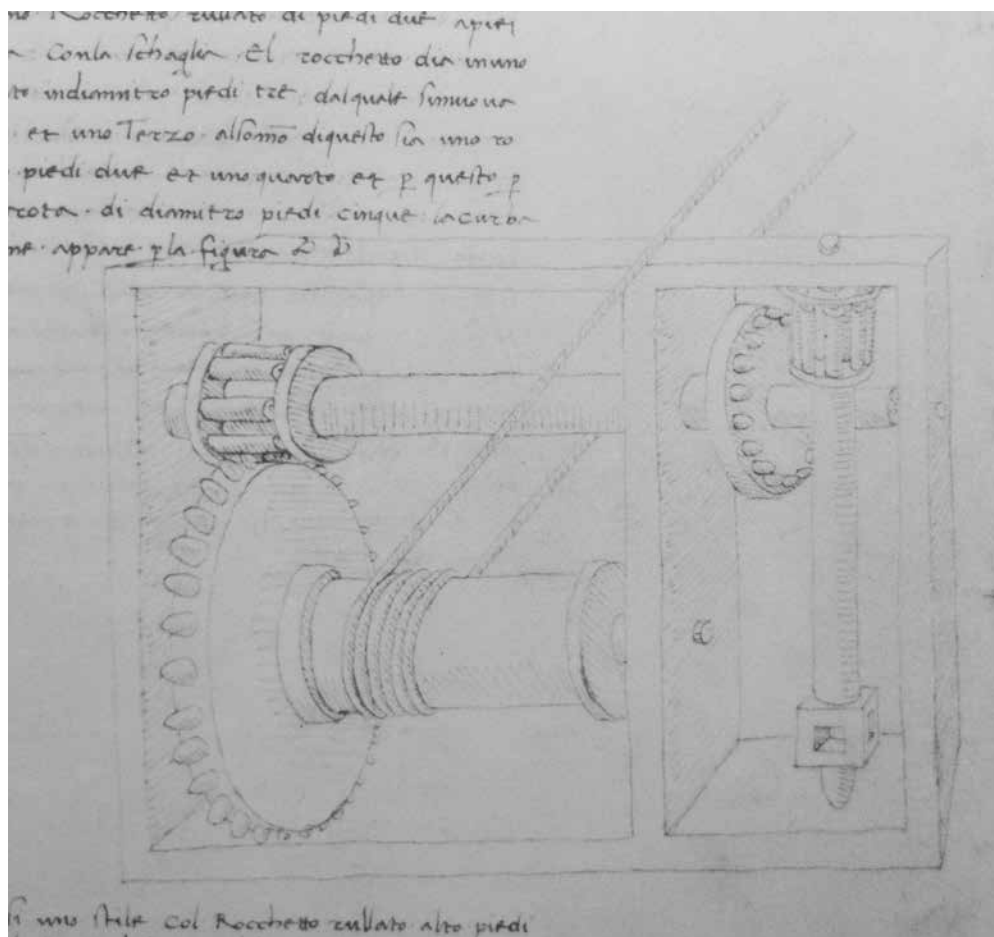
¹³ "E con questi è da por fine alla parte degli instrumenti per tirare pesi per edificare, sì perché (da) questi facilmente delli altri si porrà componare". In my transcriptions (here and subsequently) I follow the exact wording of Magliabechianus II.I.141 in comparison with Maltese's and following his standards of transcription, see DI GIORGIO MARTINI, *Trattati...* cit., II, p. 499.

¹⁴ Examples are introduced with: "In altro modo", "Per altra via", etc. Maltese suggests the treatise had undergone stylistic revision by a humanist, see DI GIORGIO MARTINI, *Trattati...* cit., I, pp. LI sg. On the streamlined content see Galluzzi, quoted above (note 13); on concentrating the examples to exemplify and safeguard one's knowledge, see also LONG, *Picturing the Machine...* cit., p. 128 and pp. 130-131. Long rediscussed the two works in P.O. LONG, *Artisan/Practitioners and the Rise of the New Sciences, 1400-1600*, Corvallis 2011, especially pp. 41-47, stressing that the later work was much better suited for an erudite readership, with which I fully agree.

¹⁵ However, when quoting the architect's abilities from Vitruvius, he explicitly mentions the paramount relevance of the drawing: "E pertanto bisogna che in più facultà isperto sia. In prima in nelle descresioni delle figure o dipenture como sono disegnatori [...] siccome detto, quanto el disegno necessario sia in prima è da vedere, senza el quale nissuna forma comporre né edificar si può", DI GIORGIO MARTINI, *Trattati...* cit., I, p. 37.

¹⁶ Also note that for Francesco the mental idea eventually reveals incompleteness and flaws once realized. "Quantunque difficil sia in disegno ogni cosa dimostrare, neanco per scrittura in alcun modo molte cose spriemar non si può, perché son tante le varietà delle cose interrotte e opposte l'una all'altra che a occupare si vengano, e però necessario quasi di ciascuna cosa modello fare. Posto che molte cose all'animo dell'architetto paia facile, e che riuscir li debba, che mettendolo in effetto gran mancamenti in essi truova, in ne' quali con difficoltà reparar vi può. Io per me delle invenzioni che qui demonstrate seranno, d'assai buona parte, in me non confidando, spirienza ho veduta". The statement introduces the levers and mills, see DI GIORGIO MARTINI, *Trattati...* cit., I, p. 142. A partial translation in LONG, *Picturing the Machine...* cit., pp. 122-125, inspired my translation of the sentence "Considering [...] difficulty", though mine is more literal. About one mill Francesco states that "meglio figurato che discrivar si può", see DI GIORGIO MARTINI, *Trattati...* cit., I, p. 148.

¹⁷ Francesco mentions experiments also when writing on pumps: "i pestrini [...] avendo spirimentato molte varie e nove fantasie da potersi in molti luoghi esercitare con acqua o senza" (DI GIORGIO MARTINI, *Trattati...* cit., I, p. 142), and states having studied singular aspects, see DI GIORGIO MARTINI, *Trattati...* cit., I, pp. 144-145, p. 169. In the treatise, he writes about columns "le quali proporzioni io con gran diligenza e non con piccola fatica per sperienza ho trovato, visto e misurato più e più volte, sicché [...] concludare la regola generale, come el altre universali conclusioni da le sue particolari riceve verità e notizia", see DI GIORGIO MARTINI, *Trattati...* cit., II, pp. 378.



confusion is only in the eye of the beholder who expects to see a "coherent" axonometric projection. Francesco offers instead a combination of views: single parts follow a particular projective logic to show key aspects adequately – Francesco refers to the medieval tradition of flat representation – whilst integrating the whole into modern projection for an overall representational logic. By doing so, he reveals his consciousness about the overall viewing habits tending towards increased familiarity with linear perspective²⁷.

The same device is discussed in the treatise as the fourth type of the *argani* (cranes)²⁸:

Another way to make [such a machine] is to make a rod thick one and a third feet and as long in height as is necessary. On top of it there is positioned a lantern gear (*rullato rocchetto*) of two feet and at its bottom end is a cube on a peg (*stampa con la scaglia*). The lantern gear engages with a crown gear (*ribeco per piano dentato*) with a diameter of three feet, which moves a rod one and a third feet thick with at its end a lantern gear of two and a quarter feet in diameter. The latter engages with the teeth of the

spur gear five feet in diameter and the drum of two and a half feet in diameter, as is shown in the figure yy²⁹.

Here, the description features detailed measurements without specifying the material. The illustration (fig. 3) shows a new composition of the device, in two separated spaces. The larger one hosts the drum and the smaller one the capstan. Once again, the draught animal is missing. The changes attest to Francesco's effort of revising not only the selection of devices and their description but also the instruments themselves.

The second device to be discussed is found among the hauling machines of the handbook:

One should make a frame and at its end a box. In this box is the worm wheel (*rocchetto*) and the worm (*vite*) moves the former; the latter can be operated from above [the box] through the crank (*manovella*). The diameter of the worm wheel is two and a half feet and the moved rod is six feet long. At the rod's end, there is a worm which connects with the spur rack (*stile*) below. The latter rests on connected rollers and is moved by the worm. And the object you wish to move can be attached to the spur rack (*dentato stile*) by chains and links of iron (*catene e rappe di ferro*). This [machine] can also be changed between one place and another. This is shown in figure XI³⁰.

This short description furnishes only some measurements and little information on materials. However, from other descriptions, one may draw some general assumptions: the frames can be assumed to be made of timber – as recommended in a previously quoted description – and the worms of iron, as indicated for another device³¹. Still, the reader does not get sufficient information and the illustration (fig. 4) integrates it only partially. For example, one infers that *stile* indicates the (toothed) rack³². Some aspects remain obscure, such as the proportion between the machine and the obelisk, which seems odd; the last sentence, too, is equivocal. Francesco writes that the device “can also be changed (*permutare*)

between one place and another”, which allows two interpretations: either he intends the device to be moved from one place to another, or he intends it to be adapted to different circumstances. Let us look at how the device is described in the treatise to gain a better understanding³³:

Make a rod made of iron three feet or two and a half feet long and half a foot in diameter, where there is the cube (*stampe*) of the lever or a frame where the lever end may be inserted. This rod shall have a worm one and a quarter feet thick which connects with a worm wheel (*rotetta dentata*) with a diameter of two and a half feet. The worm wheel moves a horizontal rod (*stile per piano*), two-thirds feet thick and seven feet long. At its head there is a worm made of bronze one and a quarter feet in diameter, which is positioned upon the rack (*scala dentata*) which is half a foot thick and large and seven feet long. Below this rack, there shall be rollers made of bronze which run on rails covered in iron (*trave coperte di ferro*). At the end of the rack, there shall be attached (*inpermare*) links (*chiavi*) made of iron which are linked together in such way that one can remove one link after another as needed, while the machine itself remains untouched. The whole machine shall be enclosed in a frame of wood (*banconi o modelli di legno*) and held together by large iron belts. And because there are positioned the shafts it shall be easier to move [the object], as shows the figure³⁴.

The description offers many details about materials and measurements, which might indicate that Francesco, in the meantime, had realized the relevance of these aspects for the device's functionality and for its explanation to non-practitioners. In the illustration (fig. 5), one sees all the details clearly. The most useful is the representation of the *rulletti di bronzo* (small bronze rollers) on which the toothed rack is moved back and forth; also, the *chiavi* (links) which might be added or taken away as necessary can be discerned as a connecting element. Strikingly, we do not find any reference to the movability or versatility of the device. Francesco instead de-

Fig. 3 Mechanical device with rope, from Codex Magliabechianus II.I.141, 92r (in di Giorgio Martini, *Trattati... cit.*, II, tav. 319).

Fig. 4 Hauling machine, from Codex Ashburnham 361, f. 45r (in di Giorgio Martini, *Trattato di architettura... cit.*, f. 45r).

¹⁸ See DI GIORGIO MARTINI, *Trattati... cit.*, II, p. 550: “più volte abbi firmato el proposito di non manifestare alcuna mia macchina o strumento, perché avendo quelli intesi con grave mio incomodo, postponendo le necessità del vitto mio, non mi pare conveniente di poi sono a luce mandata sia annullata la invenzione, consistendo il secreto in piccola cosa. Ma questo ancora saria piccola molestia quando una maggiore non seguisse, peroché facendosi li ignoranti ornati delle fatighe delli altri, usurpando quelle che si gloriano quello che non è loro invenzione [...] ma quando le opare loro potessero essere presenti a qualunque le ragioni mie leggesse, facilmente si mostraria le ragioni mie tutte essere vere, come più volte nell'esamine alli astanti ho dimostrato”. On authorship, see P.O. LONG, *Openness, Secrecy, Authorship. Technical Arts and the Culture of Knowledge from Antiquity to the Renaissance*, Baltimore-London 2001; LONG, *Picturing the Machine... cit.*, p. 128.

¹⁹ “(Sic)come la figura manifesta/dimostra”, etc. Thus the demonstrative drawing always represents a specific device and may refer to a model.

²⁰ In the treatise, Francesco discusses drawing in various parts; for example, in the conclusion: “quelli che di questa mia operetta desiderano conseguire alcuno frutto, e questo è che questi tali s'ingegnino avere qualche intelligenza del disegno, perché senza quello non si può bene intendere le composizioni e parti dell'architettura”. See DI GIORGIO MARTINI, *Trattati... cit.*, II, p. 505. On vision as the most noble sense, see DI GIORGIO MARTINI, *Trattati... cit.*, II, p. 399.

²¹ For the mechanical terminology, see E. CALCHINI, *Glossario dei termini tecnici nel Trattato I (Ms. Saluzziano 148) di Francesco di Giorgio*, in *Prima di Leonardo... cit.*, pp. 452-470.

²² The two handbook manuscripts show minor differences – which in one instance are relevant to the discussion – but one cannot establish a clear hierarchy regarding thoroughness or richness of details in text and/or drawing. The drawings in Ashburnham 361 often lack details, but sometimes they feature improvements that are absent in Saluzzianus 148. The only consistency is that the Saluzzianus 148 drawings have captions, which are missing in Ashburnham 361.

²³ At the beginning, the first chapter reads: “Grandi pesi bisogna muovere da luogo ad luogo nello edificare dove senza ingegno le forze poco vagliono, e similmente l'acqua a longa distanza et in gran quantità trarre, e non meno è utile e necessario in molti luoghi far mulini [...] pistrini a vento o senza [...] adunque è conveniente a perfezione dell'opara ponere forme delle comuni più potenti e utili di ciascuna delle ditte spezie de instrumenti”, see DI GIORGIO MARTINI, *Trattati... cit.*, II, p. 550 (apparato delle varianti). Subsequently Francesco expresses his unwillingness to make his inventions public (see note 18).

²⁴ See Ashburnham 361, f. 44v/Saluzzianus 148, f. 50r. “Anco faccisi un armadura di legname col traversato fuso dove la dentata ruota di sei piei va, cacciata dal rullato rocchetto del diritto stile sopra al mozzo della vite bilicato, dove la bestia el timon guidando. E nello stil di sopra della dentata ruota un rullato rocchetto in diametro piè due, e in su denti della ruota che la curva guida che sopra a lo stile d'essa sarà, in diametro detta ruota piei cinque e la curva due. Siccome la figura V manifesta. Sieno i detti denti di ferro, e simile el fuso de' rulli e rulli di forte legno fatti. E quelli del rocchetto sopra lo stil del timone alquanto piramidali perché più facilmente pigliando lassa”, see DI GIORGIO MARTINI, *Trattati... cit.*, I, p. 191. The original text leaves some ambiguity regarding the material of the shaft.

²⁵ For example DI GIORGIO MARTINI, *Trattati... cit.*, I, pp. 190-191. Francesco recommended making lifting devices out of timber: “le lieve de' grandi pesi non con canapi sono da fare, ma un fortissimo castello di diritti traversi e ben legati legni”, see DI GIORGIO MARTINI, *Trattati... cit.*, I, p. 189.

²⁶ An earlier version of this device can be found in the *Codicetto*, f. 166r.

Fig. 5 Hauling machine, from Codex Magliabechianus II.I.141, 93r (in di Giorgio Martini, *Trattati... cit.*, II, tav. 321).

Fig. 6 Portable mechanical device, from Codex Saluzzianus 148, f. 52r (in di Giorgio Martini, *Trattati... cit.*, I, tav. 95).

²⁷ The rotational view continued to be employed, e.g. in Robertus Valturinus' *De re militari*. On axonometric representation, see M. SCOLARI, *Oblique Drawing. A History of Anti-Perspective*, Cambridge 2012 (Italian edition *Il disegno obliquo. Una storia dell'antiprospectiva*, Venezia 2005). On the engineer's representational method, see *Prima di Leonardo... cit.*; GALLUZZI, *Gli ingegneri... cit.*, and D. LAMBERINI, *Machines in Perspective. Technical Drawings in Unpublished Treatises and Notebooks of the Italian Renaissance*, in *The Treatise of Perspective: Published and Unpublished*, proceedings of the symposium (Washington, 7-8 November 1997), edited by L. Massey, New Haven-London 2003, pp. 212-234.

²⁸ See Magliabechianus II.I.141, f. 92r. "Pigliando principio dalli argani è da dichiarare alcuni modi per li quali con ragione maggior peso e più facilmente si potrà muovere", see DI GIORGIO MARTINI, *Trattati... cit.*, II, p. 495; again, the winch (*argano*) serves to indicate the whole crane.

²⁹ "In altra forma si puo fare facendo uno stile grosso uno piede e un terzo per diritto, di quella altezza che fusse di bisogno. Nel sommo del quale sia uno rocchetto rullato di piedi due, a piedi di questo stile sia la stampa con la scaglia. El rocchetto dia in uno ribecco per piano dentato, in diametro piedi tre, dal quale si muova uno stile grosso piedi uno et uno terzo, al sommo di questo sia uno rocchetto rullato in diametro piedi due et uno quarto e per questo percuoti sopra li denti della rota di diametro piedi cinque, la curva d'essa due e mezzo, come appare per la figura yy", see DI GIORGIO MARTINI, *Trattati... cit.*, II, p. 497.

³⁰ See Ashburnham 361, f. 45r/Saluzzianus 148, f. 50v. "Facci si el telaio e la cassa a la sommità d'esso. In nella quale el rocchetto e la vite battendo sopr'esso, la qual di fuore le manuelle operar si possono. El diametro d'esso rocchetto piè due e mezzo, el fuso longo piei sei, e nell'ultimo fine d'esso la vite che denti dello stile che sotto sopra rulli commesso sarà girando guidi. E con catene e rappe di ferro a quello che tirar vuoi a esso dentato stile attaccar si può. E anco da luogo a luogo lo edificio peremutare, siccome la figura XI", see DI GIORGIO MARTINI, *Trattati... cit.*, I, p. 192.

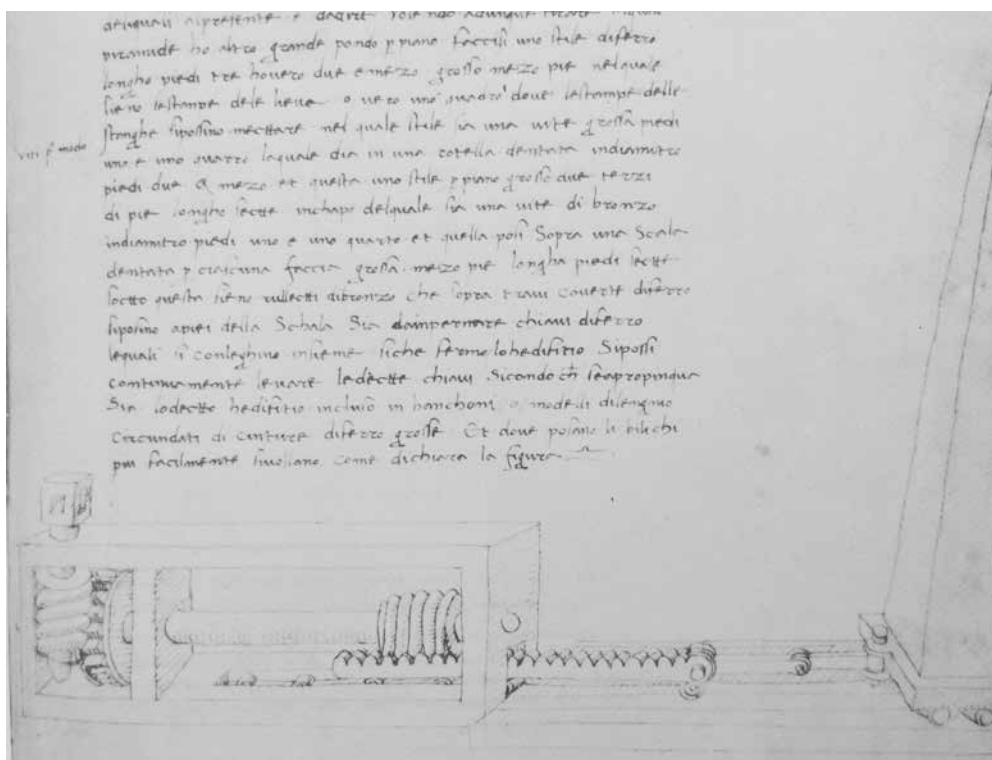
³¹ On the worm made of iron, see for example DI GIORGIO MARTINI, *Trattati... cit.*, I, p. 192. Other descriptions furnishing detailed measurements are discussed in LONG, *Picturing the Machine... cit.*, p. 122ff.

³² A sketch of this device can also be found in the *Codicetto*, f. 167v.

³³ See Magliabechianus II.I.141, f. 93r and the introduction: "Molti pesti bisogna alcuna volta muovere nello edificare che per forza di canapi non saria possibile, donde è necessario per altri instrumenti metallici a questo fine pervenire, delle forme delli quali al presente è da dire", see DI GIORGIO MARTINI, *Trattati... cit.*, II, pp. 551-552 (appendix).

³⁴ See DI GIORGIO MARTINI, *Trattati... cit.*, II, p. 498: "facci si uno stile di ferro di longhezza di tre piedi overo due e mezzo, grosso mezzo piè, nel quale sia le stampe delle lieve overo uno quadro dove le stampe delle stanghe si possono mettere, nel quale stile sia una vite grossa piede uno et uno quarto la quale dia in una rotetta dentata in diametro piedi due e mezzo, e questa uno stile per piano, grosso due terzi di piè, longo sette, in capo del quale sia una vite di bronzo in diametro piedi uno et uno quarto et quella posi sopra una scala dentata per ciascuna faccia grossa mezzo piè, longa piedi sette; sotto questa sieno rulletti di bronzo che sopra travi coverte di ferro si possono; da piei della scala sia da inernare chiavi di ferro le quali si colleghino insieme sicché, fermo l'edificio, si possi continuamente levare le ditte chiavi secondo che se appropinqua. Sia lo ditto edificio incluso in banconi o modelli di legno, circondati di cinture di ferro grosse. Et dove posano li bilichi più facilmente si vollano, come dichiara la figura". The concluding comment is ambiguous if not unintelligible, but when considering the drawing one can hypothesize that it explains the rods of the obelisk's transportation platform.

³⁵ DI GIORGIO MARTINI, *Trattati... cit.*, II, p. 498, see also CALCHINI, *Glossario... cit.*, p. 454 and 461.



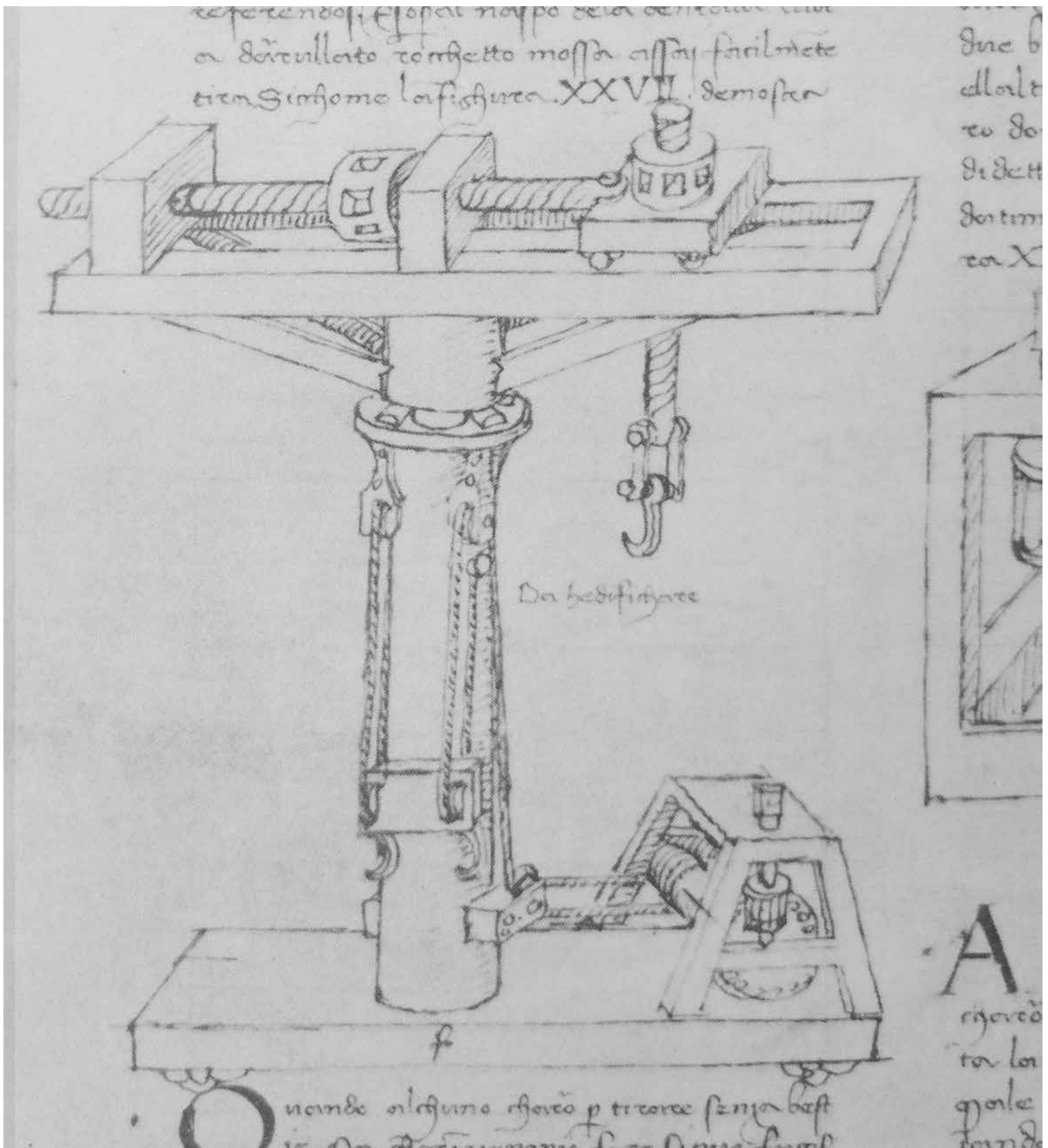
scribes the *banconi* or *modelli* (large tables or frames), which were not part of the description in the handbook³⁵. Thus, we might hypothesize that in the handbook's description Francesco wanted to point out the device's portability but later came to the conclusion, expressed in the treatise, that the device required more stability to be effective³⁶. Such a reconsideration seems even more likely when we consider that the present device was not Francesco's own invention. Instead, it was part of a series of several machine designs based on Filippo Brunelleschi's machines for the construction of the cupola of Florence Cathedral³⁷. Thus, Francesco worked on improving a device that was essentially known through drawings without any verbal description. These drawings were copied many times and are present, in a fairly identical manner, in a number of machine drawing compilations such as Bonaccorso Ghiberti's *Zibaldone* (Florence, Biblioteca Nazionale Centrale, Banco Rari 228, f. 126v)³⁸. Regarding Francesco's version, his genuine contribution consists in the description and, for the treatise, in his attempts to improve the device³⁹. A third device explicitly dedicated to construction is in the handbook preceded by a statement on its portability⁴⁰:

One might also put a post on a cart. At the top of it, the construction (*edifizio*) is positioned on small rollers (*rulli*) in the manner of a compass (*a uso di*

bossola) [i.e. slewing-gear]; here the horizontal and vertical screws enable one, thanks to the screw nuts with holes (*stampate vezzose*) and the screws (*lomache*) at both ends, to raise or lower any weight attached to the hook of the screw, and to set it down wherever one wishes. Under the compass (*bossola*) there are two pegs (*caviglie*) and two pulleys (*carrucole*); the ropes are tied to these pegs. These ropes pass by the pulleys of the wooden stopper with hooks (*uncinato ceppo*), but first they pass by the pulleys above the pegs and then go down to the two pulleys below [the wooden stopper]. And [the rope] is coiled up easily thanks to the lantern gear which turns the spur wheel⁴¹.

The jack's mobility is stressed along with the possibility of rotating its top 360 degrees horizontally, thanks to a slewing-gear (*bussola sopra rulli*)⁴². However, to understand the complex description of the various passages of the ropes, one needs the illustration (fig. 1)⁴³. Thus, one discerns which pulleys and pegs the description refers to and gains a better understanding of the device as operating in two steps. Interestingly, the gear-moved jack described is represented exclusively in the drawing in Saluzzianus 148, f. 52r (fig. 6), while the Ashburnham 361, f. 46r shows a simplified hand-moved jack. In the treatise, the device, described as *argano* (crane), is more easily understood:

Finally, regarding the cranes [operating] with ropes, there is a way by which the prepared stones and other heavy weights can be lifted up and brought to any place (*a sesta in ogni parte locare*) which might suit



the architect. Its composition is realized by building a cart on wheels on which one shall position an upright post with a height equal to the desired building. Below the compass-joist (*bossola*) one locates the pulleys of the block and tackle (*carrucole*) where the rope of the lower pulleys (*taglie*) go. The rope is doubled by them and then goes to the pulleys which are attached on the lower part of the post. In

passing through them the rope then engages with the winch (*argano*). Afterward, on top of the compass-joist there is positioned a doubled frame with [a piece similar to] a shim (*riparella*) at the top end of the rod of the compass-joist, through which passes the screw. At the other side of the shim there is a screw nut with holes (*stampe o femminelle*). On this frame is positioned a small carriage (*mozzo rulla-*

³⁶ Obviously, the increased stability goes together with increased weight, which would essentially impede movability.

³⁷ For an introduction, see GALLUZZI, *Gli ingegneri...* cit. Moreover, Gustina Scaglia interpreted drawings from the second half of the fifteenth century as documenting inventions by Brunelleschi for the Florentine cupola, see G. SCAGLIA, *Drawings of Machines for Architecture from the Early Quattrocento in Italy*, "Journal of the Society of Architectural Historians", 25, 1966, 2, pp. 90-114. Scaglia dates the combination of worm-gear and screw and slider to 1436, based on stylistic attribution of the capital shown in the device's represen-

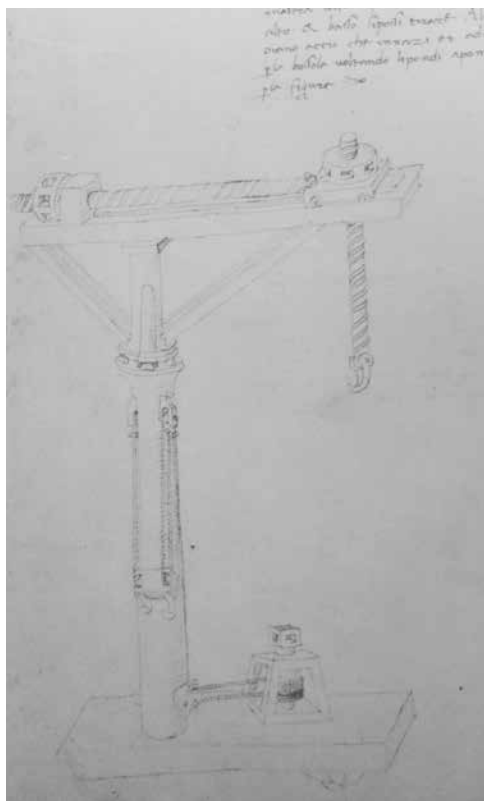


Fig. 7 Portable mechanical device, from Codex Magliabechianus II.I.141, 92v (in di Giorgio Martini, *Trattati... cit.*, II, tav. 320).

tation in Codex S. IV. 5, f. 86v (Siena, Biblioteca Comunale), while the worm-rack was developed at “some unknown time, but surely before the obelisk series”, see SCAGLIA, *Drawings...* cit., p. 106-107. Scaglia’s bold hypotheses, however, lack conclusive evidence.

³⁸ See SCAGLIA, *Drawings...* cit., p. 108, fig. 19 and Appendix A for the stated correspondence with other machine drawings, that is: with Codex Palat. 767, f. 197r; Codex Marc. Ital. Z. 86, f. 35r; Codex Barberini Lat. 4424, f. 62r-b; Codex NL 383, f. 21v (Turin, Biblioteca Reale) and Codex S.IV.1, f. 128v (Siena, Biblioteca Comunale). Dating of one manuscript before another cannot be clearly established.

³⁹ Similarly, Gianluca Belli has proposed that most of the hauling machines were essentially theoretical experiments, see G. BELLI, *Colonne, obeliscchi, piramidi. Le macchine per lo spostamento dei grandi pesi*, in *Prima di Leonardo...* cit., pp. 147-154, see p. 147.

⁴⁰ “Quando alcuno edificio a murare s’avesse, faccisi el lavoro del legname sopra a rotelli”, di GIORGIO MARTINI, *Trattati...* cit., I, p. 194, see Saluzzianus 148, ff. 51v-52r (all devices labelled *per/da hedificare*) and Ashburnham 361, f. 46r.

⁴¹ See Ashburnham 361, f. 46r/Saluzzianus 148, f. 52r. “Anco l’antenna sopra rullato carrozzo si facci. E in nella sommità, dove lo edificio a uso di bossola sopra rulli posto, che le viti per piano e per diritto, dove per le stampate vezzose e lomache innanzi e indietro, alto e basso ciascun peso dall’ocin della vite preso, dove a te piace posando fermar si può. E sotto della bossola due caviglie e carrucole, a le quali caviglie el canape attaccato, per le carrucole dell’ocinato ceppo passando, entrando per quelle da le caviglie a quelle due dabasso referendosi. E sopr’al naso della dentata ruota dal rullato rocchetto mossa assai facilmente tira, siccome la figura XXVII dimostra”, see DI GIORGIO MARTINI, *Trattati...* cit., I, p. 195. The closing remark corresponds more directly to the drawing in Codex Saluzzianus 148, f. 62v, where one discerns a reel with spur and lantern gear combination, see fig. 6.

⁴² This efficient metaphor is used also for another construction jack, see CALCHINI, *Glossario...* cit., p. 453.

⁴³ No model of this crane is to be found in the *Codicetto*.

⁴⁴ See Magliabechianus II.I.141, f. 92v. “Finalmente quanto al tirare di canapi, è da porne uno modo per el quale le pietre concie e altri gran pesi in alto e a sesta in ogni parte locare si possi dove all’architetto piacesse. La forma di questo è fac-

to) through which passes a second screw, on which is fixed the screw nut with holes, by which one can raise and lower [the objects]. At the carriage is attached the horizontal screw so that one can move the weight back and forth and by turning the compass-joint the objects can be collocated, as is shown better in the figure⁴⁴.

Here Francesco first combines the two steps of the movement – *tirare* (lift) and *locare* (positioning) – but later explains them one by one. The reference to the necessary height of the *intenna* (post), which should correspond to the height of the building under construction, is interesting, and so is the fact that he again employs the term *bossola* (in the sense of turntable)⁴⁵. He specifies details such as the horizontal screw moved by a *vezzosa* (screw nut), the doubled frame (*telaio duplicato*), and the position of the screw on a small carriage (the *mozzo rullato*)⁴⁶. Thus, the description offers more details and, most importantly, new technical expressions (also *locare a sesta, riparella, femminella*), but gives only relative measurements. Therefore, the relevant improvement of the vocabulary and the structure indicates Francesco’s increased understanding of the description’s ambiguities. The illustration (fig. 7) reveals a little gem in its representational method: while the main features are similar to the handbook, the junction of the upright post and the superimposed screw is drawn in a transparent view. The upper horizontal part rests on a vertical pillar, fixed with two diagonal battens, and the transparent view reveals that it fits loosely on a round peg. Thus, one discerns how the complete rotation of the upper part is obtained. Francesco had employed partial transparency before, in the handbook, so I suggest that in this case he applies it intentionally to improve the transmission of information, which again attests to his effort of revision⁴⁷.

We should briefly address the striking lack of measurements in both the handbook and the

treatise, which might be considered a strategy. It would be necessary to have a professional education (or to consult a professional) to assemble the device. I agree with Long that generally simplifying the descriptions stems partially from a fear of theft⁴⁸. In this case, it might be caused by the specificity of the device itself, as its measurements depend on the ones of the building under construction. Moreover, we need to take into account that the device again goes back to an invention of Brunelleschi. We do not have an original drawing, but only a short description in the “Vita” of Brunelleschi⁴⁹, as well as various drawings representing the crane in copy books dating approximately from the 1470s onwards⁵⁰. Francesco interestingly shows an additional feature, the *bossola*, which seems to have exactly two parallels. One is a near-identical copy of Francesco’s representation made by Antonio da Sangallo the Younger (GDSU, 1449 Av)⁵¹. More interestingly, there is also a drawing of Leonardo da Vinci in the Codex Atlanticus, f. 105Bv showing a similar device but with further developed elements⁵². I therefore believe that the rendering of the *bossola* in transparent view is an authentic invention of Francesco, as he probably would have reflected other aspects of Leonardo’s version, had he known it⁵³. Evidently, the crane was quite well studied and discussed at the time, and Francesco further contributed to its notoriety and visual representation.

I shall now consider the last device in the handbook, described as follows:

The cranes for heavy objects should not be done with ropes but with strong frames of horizontal and vertical, well-connected timber rods. On each side of the frame there should be a vertical spur rack which is moved by turning the worms on their top. The ladders (*scale*) have a horizontal linkage at which the weight is attached by iron chains and thereby the weight is raised. Raising the iron links and chains they can be shortened as necessary in continuously supporting the weight at the bottom.

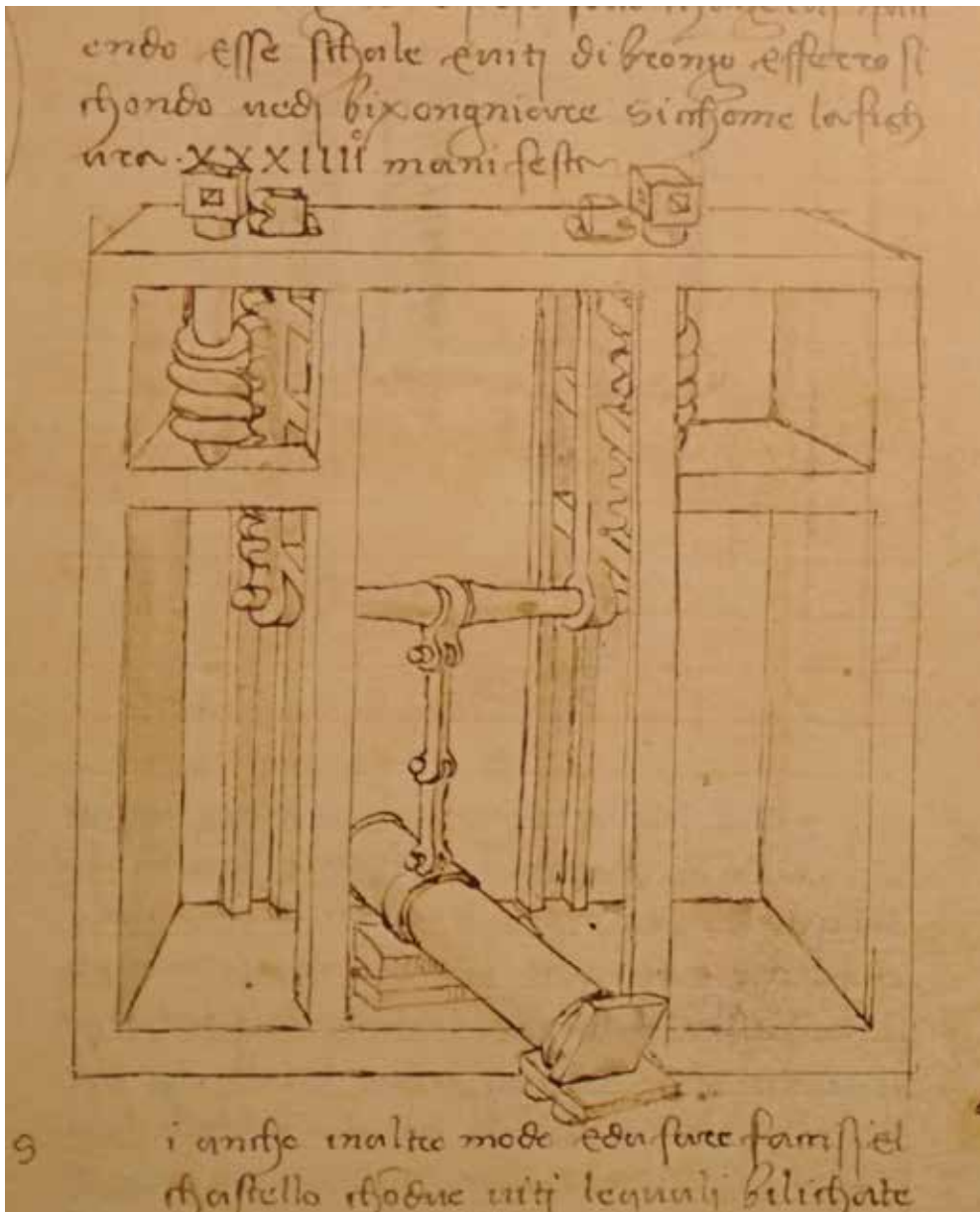


Fig. 8 Mechanical device for heavy objects, from Codex Ashburnham 361, f. 44r (in di Giorgio Martini, *Trattato di architettura... cit.*, f. 44r).

The ladders and worms should be made of bronze and iron as you think necessary. This is shown in figure XXXIII⁵⁴.

In the handbook, Francesco discusses this machine at the beginning of the section. The wording is sometimes obscure and omits details such as the source of power, which is not specified, neither in the text nor in the illustration (fig. 8)⁵⁵. The interplay between the spur rack and the worms is also quite improbable. Thus, especially after considering the drawing, we may doubt the device's functionality, not least because its dimensions are obviously symbolic: the weight of an entire column could never be supported by such a small construction. The whole description can be considered a typical example of the many difficulties which the reader of the handbook might face.

We understand this better when comparing it with the respective passage in the treatise:

To lift up in the air heavy weights it is necessary to build different instruments: these shall be made of a frame of the strongest wood with doubled and stiffened rods vertically and horizontally, inside which the crane is contained. Then one should make two racks both six feet long with the attachments for the levers, half a foot in size. At their lower end, one must position worms of bronze, each with five coils and one and a quarter feet wide; these engage with two spur racks (*scale dentate*), each half a foot wide and deep, which slide on small rollers contained in the chase. At the feet of these spur racks, there are the rings for the horizontal rod (*chiavarda da traverso*) which holds the attachments (*chiavi*), which hang down due to their weight. The latter should be composed of various parts which can be connected because when lifting up the weight and supporting it continuously

endo uno carrozzo sopra li rulli nel quale sia posata e ferma una intenna dell'altezza che debba essere lo edificio, et in essa sotto la bossola s'ordini le carrucole dove vadi el canape delle taglie; el quale, duplicato in esse, pervenga a due calcesi nell'infima parte dell'albero; el canape, passando per quelli, all'argano si conferisca. Dopo questo al sommo della bossola sia ordinato el telaio duplicato dove sia una riparella, al sommo dello stile della bossola, per la quale passi la vite, e di dietro a quella la vezzosa con le stampe o femminelle. Sopra del telaio sia uno mozzo rullato per lo quale passi una altra vite, sopra di cui si posi la vezzosa con le stampe sue, acciò che alto e basso si possi tirare. Al mozzo d'essa sia connessa la vite per piano, acciò che inanzi e indietro el peso tirare si possa, e così per la bossola voltando, li pondi a ponto si potranno collocare, come appare meglio per la figura", see DI GIORGIO MARTINI, *Trattati... cit.*, II, pp. 497-498; on *sesto* and *stampe* (equivalent of *femminella*), see CALCHINI, *Glossario... cit.*, p. 467.

⁴⁵ See CALCHINI, *Glossario... cit.*, pp. 453-454.

⁴⁶ The horizontal frame had to be provided with a central passageway to allow the horizontal movement of the vertical screw – a fact which the reader discerns only in the drawing, however.

⁴⁷ He uses them extensively in the drawings on pumps in the handbook but used them already in his *Codicetto*.

⁴⁸ Long states: "it appears that his simplifying strategy involves more than simply wanting to present a more general and rationalized account of mills. This becomes apparent when he immediately plunges into a lengthy biographical lament", see LONG, *Picturing the Machine... cit.*, p. 128, referring to the previously quoted admonition on having one's ideas stolen (see note 18).

⁴⁹ The description concerns a demonstration given by Brunelleschi between 1417 and 1419 in preparation of the construction of the cupola and is part of the "Vita of Brunelleschi" attributed to Antonio Manetti. SCAGLIA, *Drawings... cit.*, p. 98-99 quotes the relevant passage and discusses the connection of the crane's rotation to ship construction.

⁵⁰ Scaglia lists different codices and reproduces the drawing of S.IV.5, f. 17r. Some of the cited codices date after the writings of Francesco (Magl. XVIII.V.2, f. 37r; S.IV.1, f. 126v; Palat. 767, f. 201; and drawing GDSU, 1449Av attributed to Antonio da Sangallo the Younger); the connections of the others to Francesco are not fully established (S.IV.5, f. 17r; NL 383, f. 19r; Cod. II.III.314, f. 42; Cod. Atlanticus, f. 37v-b, 309r-b). Moreover, she remarks that in a copy of Taccola's *De machinis* of the Biblioteca Marciana a similar drawing has been added: cod. Lat VIII, 40 (=2941), f. 88r; see SCAGLIA, *Drawings... cit.*, p. 113/Appendix A.

⁵¹ See SCAGLIA, *Drawings... cit.*, p. 98. On Antonio da Sangallo the Younger's copies after Francesco, see *Prima di Leonardo... cit.*, p. 245-346, hypothesizing mediation through Giuliano da Sangallo. See also G. SCAGLIA, *Drawings of Machines, Instruments, and Tools*, in *The Architectural Drawings of Antonio da Sangallo the Younger and his Circle. I (Fortifications, Machines, and Festival Architecture)*, edited by Ch.L. Frommel, N. Adams, Cambridge 1994, pp. 81-92.

⁵² In Codex S.IV.5, f. 17r and the similar drawing in Ghiberti's *Zibaldone* the element is not present. GALLUZZI, *Gli ingegneri... cit.*, pp. 114-115 shows a drawing of Ghiberti of a similar turnable crane (Florence, Biblioteca Nazionale Centrale, Banco Rari 228, f. 107v) and the drawing from Leonardo da Vinci's Codex Atlanticus, f. 105Bv. While Ghiberti features the more basic version of the crane, Leonardo already shows a *bossola* which appears to be more elaborate than the one of Francesco.

⁵³ However, Mussini's dating of the treatise to 1496-1500 makes it possible that it was influenced by Leonardo, whom Francesco met around 1490 in Milan. See P.C. MARANI, *Leonardo, Francesco di Giorgio e il tiburio del Duomo di Milano*, "Arte Lombarda", 62, 1982, 2, pp. 81-92.

⁵⁴ See Ashburnham 361, f. 44r/Saluzzianus 148, f. 51v. "Perché le lieve de' grandi pesi non con canapi sono da fare, ma un fortissimo castello di diritti traversi e ben legati legni. E da ogni banda d'esso castello per diritto un dentato stile è da fare, i quali da le vite prese sopra colle manuelle girando le scale ch'el traverso dall'una e l'altra serà colle catene del ferro al peso collegate con esso peso si elevarà. E così alzandosi, rappe e catene del ferro scemando sicondo farà di bisogno, quan-

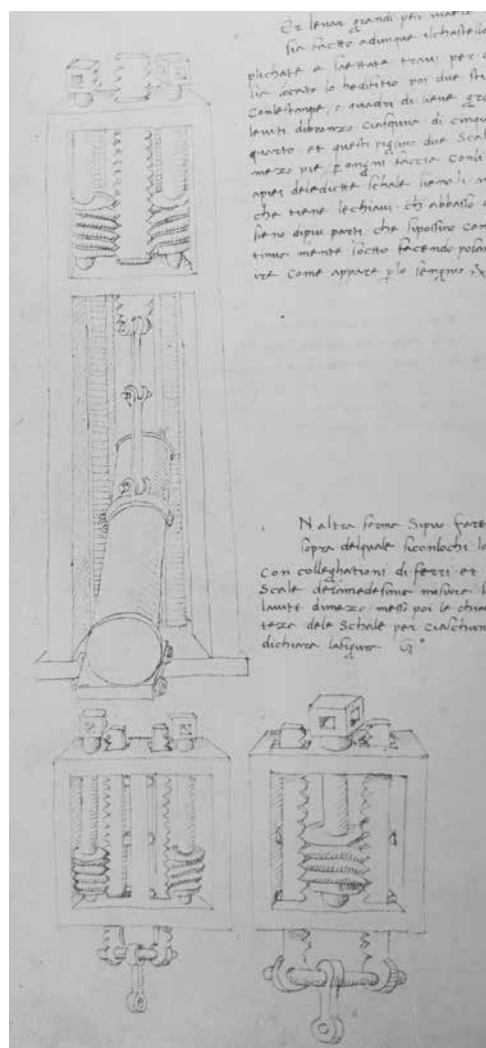


Fig. 9 Mechanical device for heavy objects, from Codex Magliabechianus II.I.141, 93v (in di Giorgio Martini, *Trattati... cit.*, II, tav. 322).

do nell'alzare el peso sotto calzerai, facendo esse scale e viti di bronzo e ferro sicondo vedi bisognare, siccome la figura XXXIII (sic) dimostra", see DI GIORGIO MARTINI, *Trattati... cit.*, I, p. 189. There, however, instead of "rappe e catene" we read "le rampe delle scommesse catene". On the support of the column, see DI GIORGIO MARTINI, *Trattati... cit.*, I, p. 189 n. 6. Maltese explains the gradual adding of plates.

⁵⁵ An earlier version of the device is shown in the *Codicetto*, f. 168v.

⁵⁶ See Magliabechianus II.I.141, f. 93r. "Per levare grandi pesi in aria, altri instrumenti fanno di bisogno: sia fatto adunque el castello di legname fortissimo di duplicate e saettate travi per diritto e traverso, nel quale sia collocato l'edifizio, poi due stili ciascuno longo piedi sei con le stampe o quadri delle lieve, grossi piedi mezzo; da piè d'essi sieno le viti di bronzo ciascuna di cinque pani grossi uno piè et uno quarto, et questi piglino due scale dentate ciascuna grossa mezzo piè per ogni faccia con i rulli nella loro incassatura, a piei delle dette scale siano gli anelli per la chiavarda da traverso che tiene le chiavi che abasso discendano per lo peso, e queste sieno di più parti che si possono connettere, perché salendo il peso, continuamente sotto facendoli posamento, le chiavi si possono diminuire, come appare per il segno -X-", see DI GIORGIO MARTINI, *Trattati... cit.*, II, p. 499.

with a [growing] pedestal, these attachments can be shortened, as is shown at the sign X⁵⁶.

The description is structured differently, and three illustrations accompany it (fig. 9): the one above represents the entire crane, the two images below show only the screw mechanism. One would expect the description to refer to the complete drawing, but it describes instead the left one of the partial drawings. Francesco gives precise dimensions and materials, and the reader can now fully understand that *scale dentate* indicates the spur racks. In the handbook, there was a distinction between *dentato stile* (spur rack) and *scale* (ladder), which indicated the ladder-like frame in which the spur rack was integrated. In the present device, this has been replaced, and the spur racks slide on rollers attached to a vertical support. The description has been changed accordingly and thus gains clarity, featuring crucial technical elements and terms. A further novelty regarding the strategy of visual communication is revealed as the device is shown by one overall view with two separate variations for screw-rack connections added as individual drawings. However, only these two additional lifting mechanisms are described, while the one featured in the general view is not mentioned. Thus, the deliberate omission of a detail in the drawing is accompanied by a more concise description. This appears to be a precise strategy to enhance efficiency. The use of partial representations might be rooted in Francesco's sketchbook practices, but adapting this strategy for an external, non-professional readership is quite an innovation, as it requires from the reader a certain ability in interpreting drawings or having at his disposal an expert to explain the text⁵⁷. That the column-lift was generally popular among Francesco's fellow engineers is attested by the numerous variations of the device recorded in various copy books and by Antonio da

Sangallo the Younger's discussion of the general drawing of Francesco (GSDU, 1443 Ar)⁵⁸.

In conclusion, the characteristics of the two writings may be summarized as follows. The rhetoric of the handbook is similar to traditional manuals in that it resembles a spoken discourse and includes plenty of details, which, however, are not provided systematically. Thus, a large part of the actual transmission of knowledge is left to the drawings. In Francesco's handbook, these drawings are often ambiguous, mainly due to the complexity of the topics addressed. In this aspect, the handbook departs from the immediate intelligibility of traditional manuals. The treatise is far better structured, and the technical terminology is explained more systematically; furthermore, the content has been streamlined. The featured devices have been perfected in two main aspects: their function and their verbal explanation. The drawings are improved as well: they now feature all the essential details discussed in the descriptions and tend to employ representational methods that are easily accessible. Thanks to the enhanced congruency between description and drawing, the reader is able to associate the technical terms with specific parts of the devices. As a result, the user can autonomously acquaint himself or herself with the terminology and the logic of the drawings.

Having compared the two writings, I think we should regard the conditions under which the reader might be autonomous as the key to his identification and, thus, to the main purpose of the texts. For the handbook, a reader with pre-existing technical knowledge and skills would be able to understand and profit from the information in the book. This kind of reader is to be found mainly among professionals such as engineers and architects. Therefore, I think that the readership Francesco addressed in his first writing were his peers. While in Urbino, he compiled a beautiful handbook putting together his

recent and previously researched material, covering all the areas an architectural practitioner had to master in order to be acknowledged as a humanist and to meet the rising standards of the learned architect, for whom there was an increasing demand among patrons and courtiers. Seen in this way, the two handbook manuscripts were possibly not conceived as models for copies (to be sold or given to clients), but as originals forming part of the library of Francesco and his workshop and which he could lend out to friends and colleagues. Additionally, the handbook served as a portfolio which Francesco could present to his patron, Duke Federico da Montefeltro, and to potential other patrons. In such circumstances, Francesco would have been present to guide his patron through the reading, complementing the information with additional technical specifications, thereby demonstrating his vast knowledge. The handbook can thus be regarded as a strong statement of the self-awareness of a late Quattrocento architect who created his own book to fulfill his increasing ambition and his need to present himself as a learned professional of a new age. The treatise instead unites all the research done by Francesco and his erudite assistants on ancient architecture and his experiences in matters of fortification. The writing testifies to his work for Federico da Montefeltro and to the high regard in which Francesco was held at the court of Urbino, resulting in an encomiastic memory of the Duke. Thus, the treatise reflects Francesco's professional development, which had taken place at the court of Urbino, but also his subsequent experiences, such as those gained during his work in Naples. Ultimately, the treatise documents Francesco's rethinking of architectural and engineering theory. In its new form with revised content, the treatise reveals a completely new concept of his architectural writing, which now fulfills the demands of a scholarly book and meets the related language standards. It pre-

serves, however, important features of Francesco's background as a practitioner, such as the use of the vernacular. It is presented in a humanistic language, with additional learned information that may be appreciated by the erudite strata, and without disregarding information that is more oriented towards application. The treatise can therefore reward every reader, regardless of his architectural or technical training, with a literary lesson on architecture and (technical) drawing. However, in order to be used for actual construction, it still required the assistance of a practitioner. Being both practitioner and scholar, the architect would know how to strike the right note when addressing courtiers and, in this way, figures like the author Francesco di Giorgio became instrumental to the treatise's success. As such, the treatise presents itself as an ideal instrument to mediate between the different classes and personalities involved in the creation of architecture, who could now all access – albeit on different levels – its extensive teachings. In sum, it constitutes a perfect representative of the new society of learning which came into being in the Renaissance.

⁵⁷ Only much later, in Sebastiano Serlio's Third Book, on antiquities, do we find something similar, when he shows variations for the upper part of the Colosseum.

⁵⁸ There he compares it to another device, similar to one of Francesco's, Magliabechianus II.I.141, f. 94r. Whereas Antonio criticizes the use of racks with movable rollers for not being sufficiently stable (see *The Architectural Drawings...* cit., cat. 219), Francesco does not elaborate further on the differences between the two. Another column-lift is shown in the handbook, Ashburnham, f. 46r/Saluzzianus, f. 51v, and has an equivalent in Ghiberti's *Zibaldone*, see SCAGLIA, *Drawings...* cit., p. 109 and appendix A, without detailed discussion.