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ANIMATION FOR THE STUDY OF RENAISSANCE TREATISES ON ARCHITECTURE. FRANCESCO DI GIORGIO MARTINI'S CORINTHIAN CAPITAL AS A SHOWCASE

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Abstract

This paper reports preliminary results of ongoing interdisciplinary research in digital humanities and animation. This research explores visualisation techniques (e.g., motion graphics, 3D animation, Non-Photorealistic Rendering) to empower the study of depicted objects in Renaissance treatises on architecture and engineering. The aim is to pioneer a method that can be adopted by both scholars in the humanities and practitioners in animation to 1) take advantage of available editions and scholarship via interactive online systems (e.g., Engineering Historical Memory); 2) map and decode visual information and knowledge embodied in manuscripts; 3) create philologically correct 3D models and storytelling to unfold narratives embedded in drawings. As a showcase, this paper used Francesco di Giorgio Martini's drawings of the Corinthian capital in the manuscripts Ashburnham 361 (*Biblioteca Medicea Laurenziana*, Florence) and Saluzzo 148 (*Musei Reali*, Turin).

Keywords

Digital Humanities, 2D Depicted Objects, 3D Animation, Motion Graphics, Visual Narrative, Non-Photorealistic Rendering (NPR), Francesco Maurizio di Giorgio di Martino, Renaissance Treatises on Architecture, Science and Technology Manuscripts

1. *Introduction: Research Background, Research Focus and Aims, Choice of the Case Study, and Structure of the Paper*

Italian Renaissance saw the introduction of drawings in treatises on civil and military architecture and engineering (Scaglia, 1992, 9-11). This practice re-joined the prestigious ancient tradition of Marcus Vitruvius Pollio's *De Architectura* ("On Architecture", 1st cent. BCE; refer to Corso, 1997) and Apollodorus of Damascus Πολιορκητικά/*Poliorketiká* ("Siege Engines", 2nd cent. CE; refer to Ridley, 1989), whose texts were both complemented by technical drawings (*formae*, in Latin, and σχήματα/*schémata*, in Greek; refer to Corso, 2018, 49). In the case of Vitruvius, the manuscript tradition does not preserve the drawings. Early and still-extant examples of this revival of technical drawings can be seen in the thirteen-century sketchbook by Villard de Honnecourt (refer to Barnes, 2009), Guido da Vigevano's *Texaurus regis Francie* (dated 1335; refer to Settia, 2004); Giovanni de la Fontana's *Bellicorum instrumentorum liber, cum figuris et fictitiis literis conscriptus* (ca 1420; refer to Birkenmajer, 1932; Sparavigna, 2013), Mariano of Jacopo, also known as *il Taccola*'s *De ingeneis* (1419-1449; refer to Shelby ,1975; Prager, & Scaglia, 1971) and *De Machinis* (1449; refer to Shelby, 1975; Scaglia, 1971), Roberto Valturio's *De re militari* (1460; refer to Valturio, 1472; Fiore, 1978, 33-34); Antonio of Pietro Averulino, also known as Filarete's *Libro architettonico* ("Architectonic book", ca 1464), and Francesco Maurizio di Giorgio di Martino's manuscripts of the *Trattato di architettura, ingegneria e arte militare* ("Treatise on architecture, engineering and warfare"; refer to Fiore, 1978; Galluzzi, 1991; Fiore, 1992; Biffi, 1997, 532-535: *Il corpus martiniano*).

Francesco di Giorgio Martini's *Trattato* was one of the major works of the Italian Renaissance (Promis, & Saluzzo, 1841, 5-10; Maltese, & Maltese Degrassi, 1967, xi-lxiv; Fiore, 1978, 142-152; Marani, 1979, xi-xxv; Mussini, 1991, 58-136; Merrill, 2013; Tapinassi, 2016, 33-62). This treatise focused on both civil and military architecture. It not only fully acquired the theoretical knowledge of antiquity transmitted by Vitruvius but also complemented the manuscripts with drawings that demonstrate a practical and didactic purpose (Bertocci et al., 2019).

Martini's work is a career-long endeavour dated between 1472 and 1495 (refer to Papini, 1946, I; Luigi Firpo, in Marani, 1979, vii-ix; Scaglia, 1991; Mussini, 1991, 82-89; Payne, 1999, 89-110). The extant manuscripts are filled with practical guidance and theoretical exempla that construed architecture as a discipline rooted in arithmetic and geometry, and implemented through drawing ("*disegno*"), creativity ("*ingegno*") and invention ("*invenzione*"); refer to Filippo Baldinucci (1681, 183-184, 265, 270, respectively). The architect, according to Martini, is an artist, inventor, and technician, and can earn this title only after years of study and on-site training (Scaglia, 1991, 62).

Notwithstanding the numerous studies on Italian Renaissance treatises on architecture (see a literature review in Payne, 1999[1]), in general, and Francesco di Giorgio Martini's manuscripts on civil and military architecture and engineering, in particular (refer to Saluzzo, 1841; Reti, 1963; Maltese, & Maltese Degrassi, 1967; Scaglia, 1970; Marani, 1979; Mussini, 1991; Mussini, 1994; Biffi, 1997; Merrill, 2013; Lugli, 2015; Tapinassi, 2016); a comprehensive study that compares the drawings in different manuscripts is still lacking. This comparative study is needed to fully appreciate the value of the visual knowledge embedded and transmitted in the manuscripts and their relationship with the texts.

The authors of this paper filled this research gap developing an interactive application for Engineering Historical Memory (EHM), whose research team has been working on interactive online systems to empower Digital History with Artificial Intelligence and Machine Learning since 2007 [2] . This paper approaches manuscript materials that have depicted objects, which is one of the main EHM research foci, and aims to pioneer a method that can be adopted by both scholars in the humanities (e.g., codicology, palaeography, history, architecture, art history, philosophy) and practitioners in the creative industry to unlock and map the complex and usually complementary relationships between texts and images in science, technology, and medicine manuscripts.

In this context, the current paper presents the preliminary results of the ongoing research started by the authors in Florence and Singapore to study the objects depicted in Renaissance Treatises on Architecture in 2019. For a synopsis on the relationships among all extant Martini's manuscripts—which contain the translation of Vitruvius' *De architectura* and original works on civil and military architecture and engineering—we refer to the study published by Marco Biffi in the *Annali della Scuola Normale Superiore di Pisa. Classe di Lettere e Filosofia* (Biffi, 1997, 532-535: *Il corpus martiniano*, which is based on and updates Maltese, & Maltese Degrassi, 1967, I, xvi-lxiv). On the next page, we propose a diagram to elucidate this matter (Fig. 1).

The project uses as a showcase Francesco di Giorgio Martini's drawings of the Corinthian capital depicted in the non-autograph manuscripts Ashburnham 361 (Fig. 2; ff. 13v-14r; *Biblioteca Medicea Laurenziana*, Florence; dated ca 1482-1486; refer to Marani, 1979 and Mussini, 1994, with facsimile edition with diplomatic transcription; Scaglia, 1992, 154-160; Biffi, 1997, 535, for the date; Vecce, 2017, 93-95) and Saluzzo 148 (Fig. 3; ff. 14v-15r; *Musei Reali*, Turin; dated ca 1482-1486, with autograph corrections by Martini; refer to Maltese, & Maltese Degrassi, 1967 for the edition and the facsimile of the folios with drawings; Scaglia, 1992, 189-192; and Biffi, 1997, 535, for the date).

This second manuscript is of exceptional importance also because it was annotated by Leonardo da Vinci on folios 13v, 15v, 25r, 27v, 32r, 41r, and 44v between 1502 and 1504 (refer to Papini, I, 219-222; Vecce, 2017, 94-95). This is the only extant manuscript annotated by Leonardo that has been identified so far. However, Giuseppina Scaglia doubted that "Leonardo could have acquired a vellum manuscript. His library comprised mostly printed books, excepting a few manuscripts on paper" (Scaglia, 1997, 155). She argues that the manuscript was annotated by Leonardo when it was in the scriptorium of Monte Oliveto Maggiore, ca 1504 (Scaglia, 1997, 154).

[1] This book is important for providing a comprehensive literature review. However, it needs to be handled with care because of some inaccuracies that are not easily detectable by non-specialists. As an example, refer to the image reproduced both on the back cover and in Fig. 1, at page 101, which is credited as MS Ashburnham 361, f. 13v, instead of MS Saluzzo 148, f. 14v (refer to Fig. 3 for confirmation).

[2] The aim of EHM is to provide to the users an open access exploration of traditional critical editions of primary historical sources together with an automatic trove of relevant secondary literature, images, videos, and news. Among others, the EHM international research team is undertaking an ongoing interdisciplinary endeavour to explore different visualisation techniques (e.g., photogrammetry, 3D laser scanning, motion graphics, 3D animation, Non-Photorealistic Rendering) for the philological study and facsimile publication of science, technology and medicine manuscripts (refer to the EHM website).

The two manuscripts are copies of the so-called *Trattato I* ("First Treatise"), whose lost archetype was composed between 1478 and 1481 (refer to Biffi, 1997, 533, footnote 4, and 579, footnote 133) when Martini was working for Federico III da Montefeltro (refer to Papini, 1946, I, 127, 161). These are the only two items among Martini's manuscripts that contain drawings of the Vitruvian narrative of the origin of the Corinthian capital.

The present paper is structured in four sections (including this introductory one and the conclusions) followed by acknowledgements (research collaborations and funding), and bibliographical references. Section 2 presents and discusses the drawings related to the Corinthian capital that are depicted in the two copies of *Trattato I* by Francesco di Giorgio Martini. Section 3 showcases how to create philologically correct 3D models of the drawings and decode their embedded narratives. Section 4 draws the conclusions about the pioneering of an interdisciplinary method to create 3D animated models and storytelling for both scholars in the humanities and practitioners in animation.

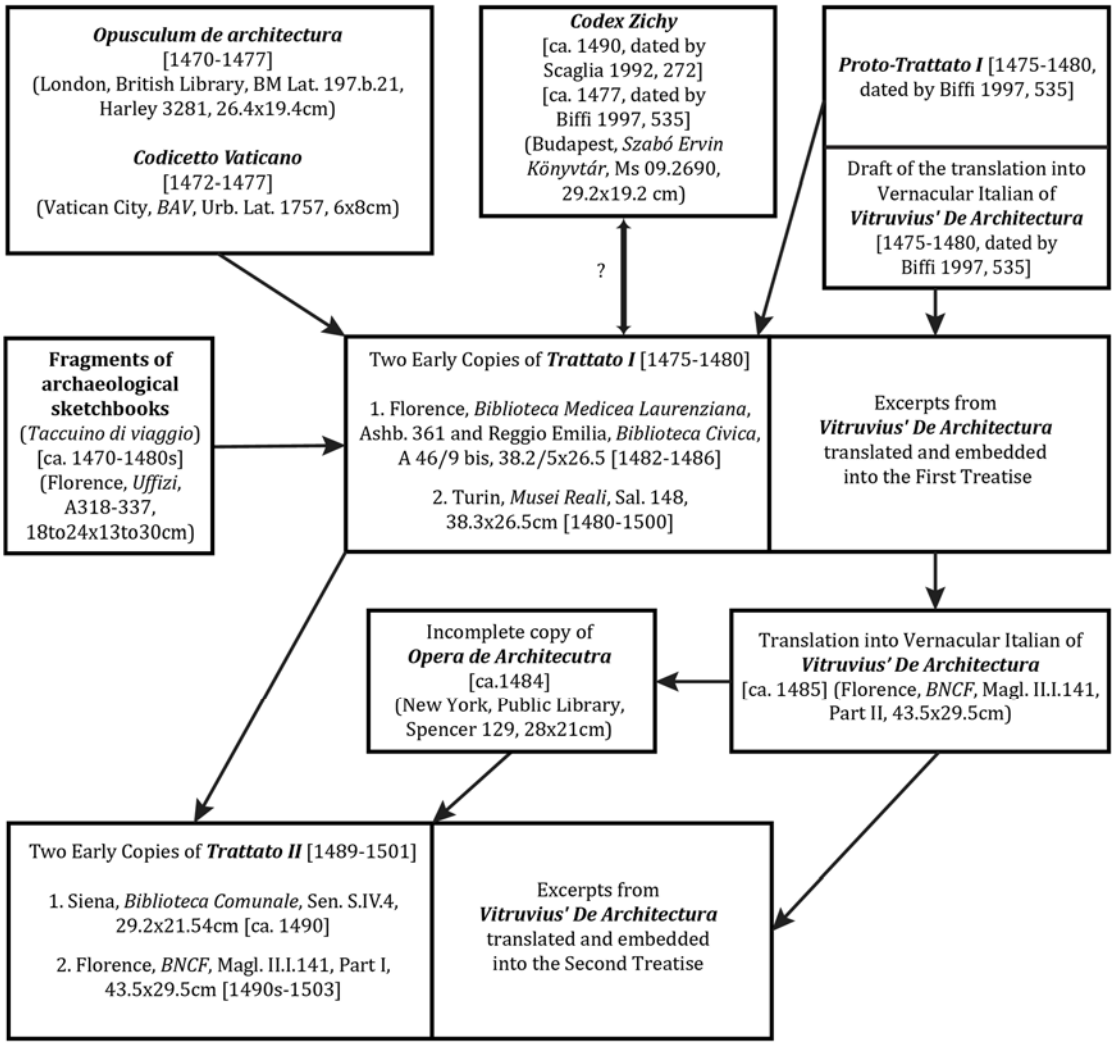

Fig. 1: Diagram of the corpus of the manuscripts of Francesco di Giorgio Martini drawn on Adobe Illustrator® by Zaqeer Radzi in November 2020. The description of the manuscripts is based on the work of Giustina Scaglia (1992, 43-50, 51-52, 53-55, 55, 58, 154-160, 189-192, 210-212, 251-258, 274-277) apart from *Codex Zichy*, whose description along with the structure of this diagram refers to Marco Biffi (1997, 535; Francesco di Giorgio Martini, 2002, *Introduction*). In this diagram, the relationship between *Codex Zichy* and *Trattato I* (refer to Mussini, 1991, 82-89) is labelled with a double-headed arrow accompanied by a question mark to indicate disagreement in scholarship: Scaglia (1992) dates *Codex Zichy* after *Trattato I* while Biffi (1997) dates *Trattato I* after *Codex Zichy*. For the fragments of the sketchbooks (entitled *Taccuino di viaggio* by Bartoli, 1914, I, pls. VI-IX), which is not included in Biffi's diagram, also refer to Papini (1946, I, 46, and II, with the reproduction of all drawings in Figg. 16-26, 28, 29, 32-34, 36-40, 42, 43, 59-63, 65-68), Orfanos, 1973, 4-10, and Burns, 1994.

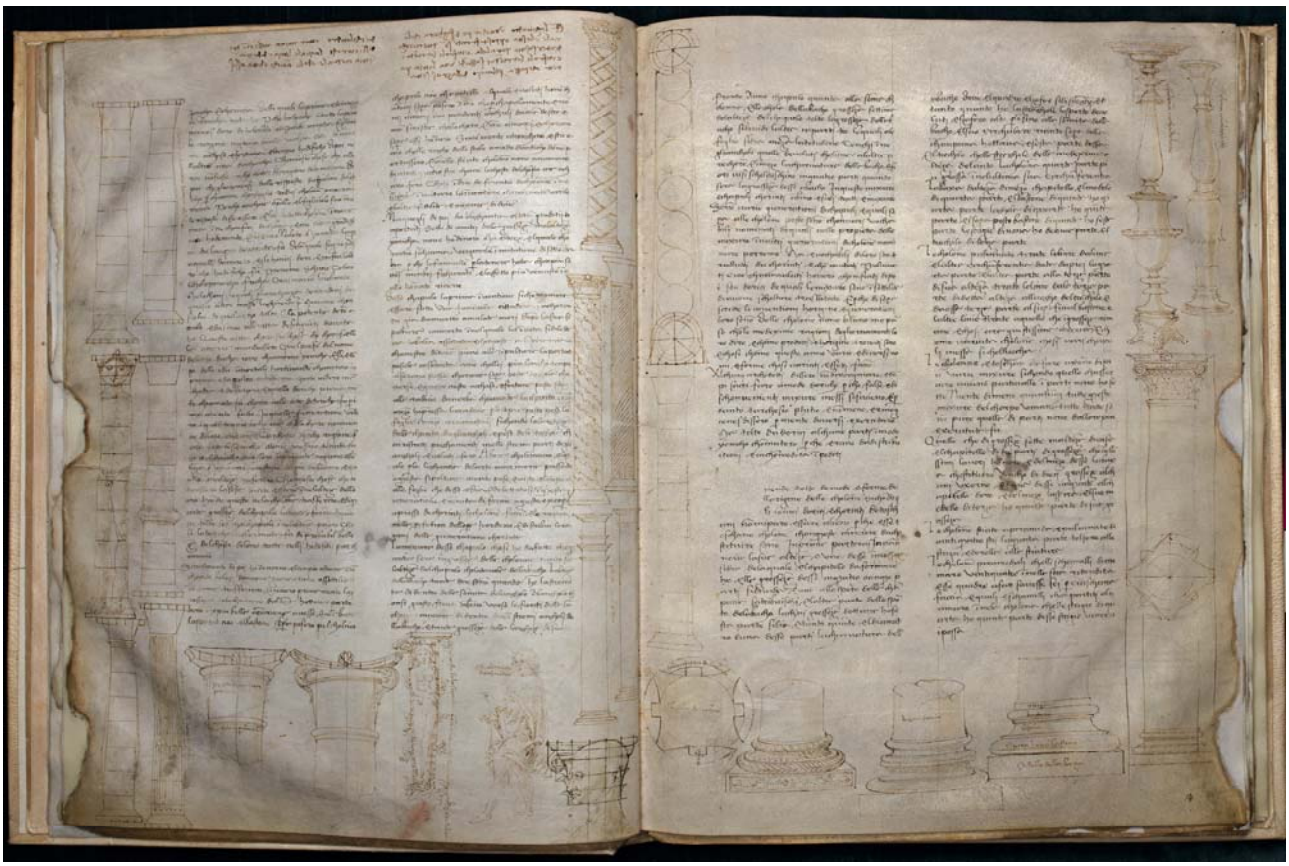

Fig. 2: Reduced-size image of folios No. 13, verso, and 14, recto, of Francesco of Giorgio Martini's *Treatise on Civil and Military Architecture (Trattato I)* ink on parchment, held in the *Biblioteca Medicea Laurenziana* of Florence (MS Ashb. 361, ff. 54, 38.2-38.5x26.5cm) with a fragment in the *Biblioteca Civica "Antonio Panizzi"* of Reggio Emilia (MSS Reggiani A 46/9 bis, ff. 4, 35.2x26cm). Folio 13v has a note written by Leonardo da Vinci about the cylinder, which is dated ca 1504 (Scaglia, 1992, 154; Swetz, 2010): *El chilindro è un chorpo di fighura cholon-/ nale e lle sua opposite fronte son due cierchi / d'interpositio paralella. E infra li lor cientri / {e infra li lor cientri} s'asstende una linia {pa} / retta che passa per il meço della grossetta // del chilindro e ttermina nelli cientri / d'essi cierchi, la quale linia è ddetta / linia cie[n]trale e dalli antichi è detta assis* ("The cylinder is a shape of columnar form, and its opposite ends are two circles / parallel to each other. And between their centres a straight line stretches through the centre of its thickness // and ends in the centres / of the circles; this line is called / the 'central line', and 'axis' by the ancients"; critical transcription by Andrea Nanetti and English translation by John Melville Jones; for a diplomatic transcription, refer to Marani, 1979, 115). Folios 13v and 14r are endowed with 16 and 9 drawings, respectively, which are disposed along the left margin, below the text as well as in the right margin of both folios. The drawings refer to the classical architectonic orders described in chapters LII and LIII of the treatise: *l'origine e ragione de le cholonne* ("the origins and characteristics of columns"; f. 13r, Ch. LII, ll. 1-2). The proportions of the Corinthian order are represented in the four columns on the upper left and in the head in the bottom right of f. 13v. The four columns show the design of the modular scheme of the order (refer to Migliari, 1994). One column shows the module (M) referred to the diameter of the column itself: base ½ M; barrel 7+½ M; capital 1M; for a total of 9 modules in height. The method for drawing the double entasis of the shaft of the column is represented in another drawing which shows how the entire column is proportionate to the human figure (base = feet; shaft = body; capital = head). — The digital photographic documentation (RAW files) was made by the University of Florence in 2019 (DIDALABS, photographer Matteo Bigongiari; refer to Bertocci, Pivetta, & Bigongiari, 2019); NIKON D850. Adobe Bridge Camera Data of the original .nef files acquired in the visible spectrum: camera NIKON D850, lens 24mm f/1.8, f/9.0 1/60, ISO100, Untagged RGB, 48.49 MB, 300dpi, 8256 x 5504; Data Time Original 09/08/2019). The image reproduced here has been colour calibrated with Adobe Camera Raw® and resized on Photoshop® by Oen Weng Wah Nicholas at the School of Art, Design and Media in Nanyang Technological University, Singapore in 2020. Adobe Camera Raw allowed to tweak the colours and other properties of the image. Thus, the user experience of the reduced-size images is closer to the original manuscript in its library setting under natural lighting. This colour calibration is based on the Color Rendition Chart (CRC) placed by the photographer on the right side of the original digital image of the manuscript, which has been cropped in this reproduction. © Florence, *Biblioteca Medicea Laurenziana*. Published with permission ("su concessione del Ministero dei beni e delle attività culturali e del turismo, MiBACT - BML - Prot. 2789/28.13.10.01/2.29"). See Saluzzo, 1841; Maltese, & Maltese Degrassi, 1967; Marani, 1979; Mussini, 1991; Mussini, 1994; Biffi, 1997.

Fig. 3: Reduced-size image of folios No. 14, verso, and 15, recto, of Francesco of Giorgio Martini's *Treatise on Civil and Military Architecture (Trattato I),* ink on parchment, held in the *Musei Reali* of Turin (MS Sal. 148, ff. 100, 38.3x26.5cm). For a transcription of this manuscript and the reproduction of the pages with drawings see Maltese, & Maltese Degrassi 1967, I. Folios 14v and 15r are endowed with 16 and 12 drawings, respectively, which are disposed along the left margin, below the text as well as in the right margin of both folios. These drawings refer to the origins and characteristics of columns in the classical architectonic orders described in chapters LII and LIII of the treatise (*l'origine e ragione de le cholonne*, "the origin and explanation of columns", f. 14v, Ch. LII, ll. 1-2). — The .jpeg files of the single folios provided by the *Musei Reali* have been assembled and optimized for the publication by Davide Benvenuti. © Turin, *Musei Reali*. Published with permission ("Convenzione, 6 ottobre 2020"). See Saluzzo, 1841; Maltese, & Maltese Degrassi, 1967; Biffi, 1997.

2. *Analysis of the relationship between texts and drawings related to the Corinthian capital in "Trattato I" by Francesco di Giorgio Martini*

In the first century BCE, the Roman architect, civil and military engineer Marcus Vitruvius Pollio (ca 80-70 BCE – post ca 15 BCE) reported about the origin of the Corinthian architectural order in his *De architectura libri decem* ("The Ten Books on Architecture", Book IV, Ch. 1. *The Origins of the Three Orders, and the Proportions of the Corinthian Capital*, 8-12; English translation by Morgan, 1914; based on Vitruvius Pollio, 1912). Francesco di Giorgio Martini embedded the translation of these excerpts in Chapter LII of *Trattato I* (Fig. 2, MS Ashb. 361, ff. 13v-14r; Fig. 3, MS Sal. 148, ff. 14v-15r; Marani, 1979, 28-29) and added to the page several drawings related to the Corinthian capital.

According to Martini's translation of Vitruvius, "[8.] Ma el terzo [ordine], el quale corinzio si chiama, virginale immitazione di sottilità ha, perché le fanciulle per la tenera età con più sottili menbri figurate e l'effetto più venusto innello ornato riceve"[3] (Figg. 4c, 5c, 6).

[3] [8.) *... Tertium vero, quod Corinthium dicitur, virginalis habet gracilitatis imitationem, quod virginis propter aetatis teneritatem gracilioribus membris figuratae effectus recipiunt ornatus venustiores.* "[8.] The third order, called Corinthian, is

The translation continues. "[9.] D'esso capulo la prima invenzione si commomora essare fatto. Una fanciulla cittadina a Chorintio, già da marito, amalata morì; doppo la sua sipoltura in un orto innel quale lei, in vita, si dilettava, la balia assettata e conposta, in un piramidale canestro, di terra pieno, alla sipultura la portò e pòsela in sommità; acciò che llei più longo tenpo al sereno stesse cor una sopra posta tegola coverse. E questo cesto a ccaso e fortuna posto sopra alla radice d'un erba chiamata l'acanto, in questo mezzo, oppressa la radice per lo sopra posto peso, le foglie i mmezzo a' ramustelli, sicondo la largheza dell'acanto dagli angoli e peso de la tegola con ristretti piegamenti inell'estreme parti degli angoli e voluti fero" [4]. (Figg. 4c, 5c, 6).

Martini's drawing of a female body (Figg. 4c, 5c) reflects and combines in one single image both the maiden's slenderness of the Corinthian architectural order (paragraph 8) and the iconographic element of the calathus that inspired this new architectural order to the Greek architect and sculptor Callimachus (paragraph 9). To do so, the basket is represented in an elongated form to be able to hold the entire figure of the maiden. In Vitruvius the calathus (Greek κάλαθος/*kálathos*, a vase-shaped basket with a flat top, made by weaving together reeds or twigs; refer to the Oxford English Dictionary, online), which was put on an acanthus root by the dead maiden's nurse incidentally, contained "a few little things that used to give the girl pleasure while she was alive". Instead, in Martini's translation, the "basket in the shape of a pyramid" (*piramidale canestro*) is "full of dirt" (*di terra pieno*). Thus, it makes sense that the acanthus leaves sprout from inside out the entire length of the basket and give the idea that the plant was growing inside the basket itself.

Comparing the Latin text and Martini's Vernacular Italian translation to the drawings of the capital, we can highlight the misunderstanding that fed Martini's visual interpretation of the Corinthian capital. In Martini's drawings (Figg. 4b, 5b), the acanthus leaves grow between the abacus and the ovolo, from inside the basket, following his translation (*el cesto colle foglie che d'esso escìa*, "the basket with the leaves coming out of it"), instead of growing around a calathus as described in Vitruvius (*eum calathum et circa foliorum nascentem teneritatem*, "the basket with the tender young leaves growing round it").

This interpretation seems to be due to the Corinthian capitals that Martini saw around him. In Martini's time, Vitruvius' description of the Corinthian capital was usually associated with both Corinthian and Composite capitals. The differentiation among these two architectural orders, already identified by Leon Battista Alberti, was formalised by Sebastiano Serlio later in the sixteenth century (Serlio, 1537, vi, five orders; Ch. VIII, Corinthian order; Ch. IX, Composite Order). Before and during the composition of *Trattato I*, as documented by his sketches of antiquities preserved in the *Galleria degli Uffizi* (Florence), Martini saw ancient Corinthian capitals, among others, close to Spoleto (Temple of Clitumnus; *Uffizi*, 321 A, verso; reproduced in Papini, 1946, II, 22), and in Tivoli (Hadrian's Villa; 319 A, recto; Papini, 1946, II, 38).

In Rome, Corinthian capitals were visible in the temples of the Roman imperial fora, which were a must for anyone who visited the eternal city (e.g., Filippo Brunelleschi, 1402-1404; Bruschi, 1998). However, numerous models were available also in Siena and Florence, where the reuse of classical finds in construction sites widespread since the Middle Ages. This practice occurred especially in Florentine Romanesque architecture where, in addition to the reuse, ancient discoveries were also taken as a model and replicated with the

an imitation of the slenderness of a maiden; for the outlines and limbs of maidens, being more slender on account of their tender years, admit of prettier effects in the way of adornment".

[4] [9.] *Eius autem capituli prima inventio sic memoratur esse facta. Virgo civis Corinthia iam matura nuptiis inplicata morbo decessit. Post sepulturam eius, quibus ea virgo viva pupulis delectabatur, nutrix collecta et composita in calatho pertulit ad monumentum et in summo conlocavit et, uti ea permanerent diutius subdiu, tegula texit. Is calathus fortuito supra acanthi radicem fuerat conlocatus. Interim pondere pressa radix acanthi media folia et cauliculos circum vernum tempus profudit, cuius cauliculi secundum calathi latera crescentes et ab angulis tegulae ponderis necessitate expressi flexuras in extremas partes volutarum facere sunt coacti.* "[9.] It is related that the original discovery of this form of capital was as follows. A free-born maiden of Corinth, just of marriageable age, was attacked by an illness and passed away. After her burial, her nurse, collecting a few little things which used to give the girl pleasure while she was alive, put them in a basket [i.e., calathus], carried it to the tomb, and laid it on top thereof, covering it with a roof-tile so that the things might last longer in the open air. This basket happened to be placed just above the root of an acanthus. The acanthus root, pressed down meanwhile though it was by the weight, when springtime came round put forth leaves and stalks in the middle, and the stalks, growing up along the sides of the basket, and pressed out by the corners of the tile through the compulsion of its weight, were forced to bend into volutes at the outer edges"

consistency of shapes and proportions. For instance, in Florence, in the Baptistery of St John, there are reused Corinthian capitals (De Angelis d'Ossat, 1962). In the nave of the *Basilica di San Miniato al Monte*, there are large Corinthian capitals that come from remains of Roman *Florentia* and eleventh-century replicas of pseudo-Corinthian capitals that are similar to the classical ones (Gurrieri et al., 1988, 39-41). In the façade of the same basilica (Fig. 7a), in the basement order, there are capitals similar to the drawings of the two earliest copies of *Trattato I*.

The translation goes on with the tale of Callimachus. "[10] Allora Chalimacco el qual'è per la leganzia de l'arte marmoria, passando a questa sipoltura, mente pose e, visto el cesto colle foglie che d'esso escìa e, delettatosi in questa generazione e nnovità di forme [Figg. 4c, 5c], a questo essenpro a presso de' Corinti le colonne fece e le ragioni nella perfezion dell'opra ordenò, e distribuì le ragioni della generazione corinzia [Figg. 2, 3]"[5].

In the drawings of *Trattato I*, the ancient sculptor appears as a Tuscan nobleman of the fifteenth century gazing at the representation of the scene that inspired him the Corinthian capital (Fig. 4d, where he is holding the tunic in his right hand and points with the other hand; Fig. 5d, where he is holding a stick on the right hand). Contrarily to the other drawings on the page, which are of critical value to the architect, this image has a quality of storytelling and illustration.

The two following paragraphs are about the proportions of the capital. "[11] La missura d'esso capulo così è da fare, che quanta serà la grosseza della colonna tanto sia l'altezza del capulo co la tavola dell'abaco. L'altezza dell'abaco tanta due sonno quanta è la stremità di dentro della sommità de l'angolo a l'angolo, con sì giuste fronti abbino verso le fronti della larghezza missura di dentro dalli stremi angoli dell'abaco. (Figg. 4a, 4b, 5a, 5b, 7). "[12.] E tanta grossezza della larghezza di sua fronte a uno capulo quanta alla somma colonna. E lla gola dell'abaco grossezza settima de l'altezza del capulo; tolto la grosseza dell'abaco si dividi l'altra in parti tre, le quali a le foglie si dia mezza latitudine. Tenghi innegli angoli quelle de' voluti che l'una a l'altra precorre. E i mmezo la curvatura dell'abaco e fiori vi si scolpischino in quatro parti quanto serà la grossezza d'esso abaco. In queste missure e capuli corinti abbino e suoi tratti e missure"[6]. (Figg. 4a, 4b, 5a, 5b, 7).

The practical information about the proportions of the capital provided by Vitruvius in the above two paragraphs is reflected in the drawing where a hairless head of a man is superimposed on the capital to stress the derivation of the canonical architectural orders

[5] [10.] *Tunc Callimachus, qui propter elegantiam et subtilitatem artis marmoreae ab Atheniensibus κατατηξίτεχνος fuerat nominatus, praeteriens hoc monumentum animadvertit eum calathum et circa foliorum nascentem teneritatem, delectatusque genere et formae novitate ad id exemplar columnas apud Corinthios fecit symmetriasque constituit ⟨et⟩ ex eo in operis perfectionibus Corinthii generis distribuit rationes.* "[10.] Just then Callimachus, whom the Athenians called κατατηξίτεχνος for the refinement and delicacy of his artistic work, passed by this tomb and observed the basket [i.e., calathus] with the tender young leaves growing round it. Delighted with the novel style and form, he built some columns after that pattern for the Corinthians, determined their symmetrical proportions, and established from that time forth the rules to be followed in finished works of the Corinthian order".

[6] [11.] *Eius autem capituli symmetria sic est facienda, uti, quanta fuerit crassitudo imae columnae, tanta sit altitudo capituli cum abaco. Abaci latitudo ita habeat rationem, ut, quanta fuerit altitudo, tanta duo sint diagonia ab angulo ad angulum spatia; ita enim iustas habebunt frontes quoquoversus latitudines. Frontes sinuentur introrsus ab extremis angulis abaci suae frontis latitudinis nona. Imum capituli tantam habeat crassitudinem, quantam habet summa columna praeter apothesim et astragalum. Abaci crassitudo septima capituli altitudinis.* [12.] *Dempta abaci crassitudine dividatur reliqua pars in partes tres, e quibus una imo folio detur; secundum folium mediam altitudinem teneat; coliculi eandem habeant altitudinem, e quibus folia nascuntur proiecta, uti excipiant quae ex coliculis natae procurrunt ad extremos angulos volutae; minoresque helices infra sinum medium, qui est in abaco, ⟨sub⟩ flores subiecti scalpantur. Flores in quattuor partibus, quanta erit abaci crassitudo, tam magni formentur. Ita his symmetriis corinthia capitula suas habebunt exactions.* "[11.] The proportions of this capital should be fixed as follows. Let the height of the capital, including its abacus, be equivalent to the thickness of the base of a column. Let the breadth of the abacus be proportioned so that diagonals drawn from one corner of it to the other shall be twice the height of the capitals, which will give the proper breadth to each face of the abacus. The faces should curve inwards, by one ninth of the breadth of the face, from the outside edge of the corners of the abacus. At the bottom the capital should be of the thickness of the top of the column omitting the congé and astragal. The height of the abacus is one seventh of the height of the capital. "[12.] Omitting the height of the abacus, let the rest be divided into three parts, of which one should be given to the lowest leaf. Let the second leaf occupy the middle part of the height. Of the same height should be the stalks, out of which grow leaves projected so as to support the volutes which proceed from the stalks, and run out to the utmost corners of the abacus; the smaller spirals between them should be carved just under the flower which is on the abacus. The flowers on the four sides are to be made as large as the height of the abacus. On these principles of proportion, Corinthian capitals will be finished as they ought to be".

from the proportions of the human body (Figg. 7f, 7g, 7h). These drawings of the capital can be associated with the four representations of the general proportion of the whole column compared to the whole human body (Figg. 2, 3, upper left).

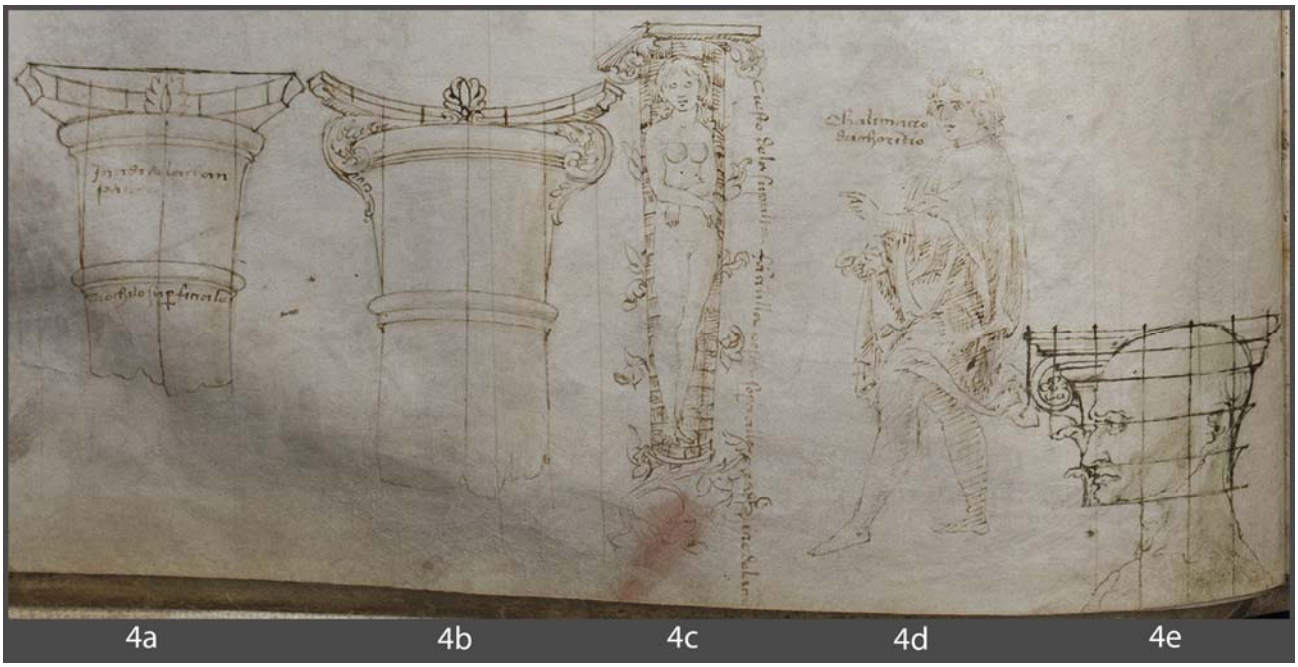

Fig. 4: Enlarged-size detail of folio 13, verso, of Francesco of Giorgio Martini's *Treatise on Civil and Military Architecture,* ink on parchment, held in the *Biblioteca Medicea Laurenziana* of Florence (MS Ashb. 361) with five drawings related to the Corinthian capital as described in chapter LII of the text of the treatise. **Fig. 4a. Pseudo-prospective view of the upper part of a column with a Corinthian capital:** from the bottom, we can see the upper part of the shaft with caption *Trochilo superficiale* ("Superficial trochile", i.e., scotia, a concave moulding; refer to Shute 1563, sig. Diii). This element separates the shaft from the calathus (i.e., basket, aka inverted bell, with caption *I nudi de la chanpa[na]*, ("The naked [volumes] of the bell", i.e., the basic volume of the capital without acanthus leaves), where the leaves of acanthus typical of the Corinthian capital are not represented), an ovolo which is not present in classical Corinthian capitals but is typical of Roman capitals, defined later as Composite (refer to Fig. 8), and a concave abacus with the standard rosette in the middle. This drawing highlights the modular design of the composition of the capital and its details. **Fig. 4b. Pseudo-prospective view of the upper part of a column similar to the previous one**: this drawing is like Fig. 4a, except that the external acanthus angular volutes, which are a standard presence in Corinthian capitals, are placed above the ovolo and grow from inside the calathus. **Fig. 4c. The burial of the Corinthian maiden that, according to Vitruvius, inspired the Corinthian capital to Callimachus**: drawing of a rectangular oblong bier with short convex sides, topped by a typical flat Corinthian tile (refer to Corso, 2005). The naked corpse of a maiden lies in a bier made from a basket: she has both arms crossed on the belly. Leaves of acanthus surround both the bier and the tile. In the caption, *Ciesto de la supulta fanciulla posta sopra alla radicie de l'acanto* ("basket of the buried girl placed above the acanthus root"), on the right of the drawing, she is identified with the Corinthian girl who died before her wedding and whose tomb inspired the Corinthian capital to the sculptor Callimachus (refer to Vitruvius, *De architectura*, IV, 1, 9-10). Antonio Corso suggests that this figure is inspired by the statue of the so-called Medici Venus reproduced in Fig. 6. **Fig. 4d. Ideal portrait of the late-fifth-century-BCE sculptor Callimachus**: he is represented while he is striding, passing by the tomb of the Corinthian girl, which will suggest him the creation of the first Corinthian capital (refer to Wesenberg, 1999; Scahill, 1997). The caption near the mouth of the sculptor (*Chalimacco da Chorintio*) clarifies that character is Callimachus and specifies that he was a Corinthian: the latter information is not known from ancient *testimonia* and may have been argued from the location of the episode at Corinth. This geographical information is not reported in MS Saluzzo 148 (refer to Fig. 5d). The ancient sculptor appears as a Tuscan nobleman of the fifteenth century who holds his tunic the right hand and points the left hand to the maiden who inspired him the Corinthian capital. This representation of the episode may be the first of a long series of visual recreations of this anecdote throughout the Renaissance (refer to Giuliano, 1994). **Fig. 4e. Capital with superimposed head**: this drawing is made with different ink and possibly by another hand. In MS Saluzzo 148 (Fig. 3), it is placed in the next folio (Fig. 7g). The calathus is endowed with the canonical three rows of acanthus leaves. Between the calathus and the abacus, we see the angular volutes with the ovolo. A hairless head of a man is superimposed on the capital to stress the derivation of the canonical architectural orders from the proportions of the human body. Horizontal and vertical lines are superimposed as well. The capital and the head compose a modular grid to help the architect and give the 'correct' measures to the different parts of the capital.

Fig. 5: Enlarged-size detail of folio 14, verso, of Francesco of Giorgio Martini's *Treatise on Civil and Military Architecture,* ink on parchment, held in the *Musei Reali* of Turin (MS Saluzzo 148) with four drawings related to the Corinthian capital as described in chapter LII of the text of the treatise. © Turin, *Musei Reali*. Published with permission ("Convenzione, 6 ottobre 2020"). **Fig. 5a. Pseudo-prospective view of the upper part of a column with a Corinthian capital:** for this drawing see the description in Fig. 4a. The captions are different: *Xofaro*; *Churvatura*; *Chanpana hover tanburo del chapulo* ("Zoophorus; Curvature; Bell or the capital as a modular element of the column"). As highlighted by Corrado Maltese and Livia Maltese Degrassi, the term *zofaro* (sic, read *xofaro*, i.e., zophorus or zoophorus, a continuous frieze bearing figures of men and animals carved in relief) is used improperly (Maltese, & Maltese Degrassi, 1967, I, 257). **Fig. 5b. Pseudo-prospective view of the upper part of a similar column**: for this drawing see the description in Fig. 4b, except for the captions *cicrami* ("fronds"; refer to Giardini Pedro, 2011, 164, Figura 25, Figura 26) on the side of the left acanthus leaf and *Trochilo* ("trochile", i.e., scotia, a concave moulding; refer to Shute, 1563, sig. Diii) below the lower astragal, which in MS Ashb. 361 is in Fig. 4a. **Fig. 5c. The burial of the maiden that, according to Vitruvius, inspired the Corinthian capital to Callimachus**: for this drawing see the description in Fig. 4c. The captions are different from the ones on MS Ashb. 361: *Tegola*; *Voluti*; *Chanestro piramidale*; *Radice et herba dell'achanto* ("Tile; Volutes; Basket in the shape of a pyramid; Root and plant of the acanthus"). **Fig. 5d. Ideal portrait of the late-fifth-century-BCE sculptor Callimachus**: for this drawing see the description in Fig. 4d, except for the caption *Chalimacco* ("Callimachus") that is missing the reference to Corinth, and adds a stick in the right hand.

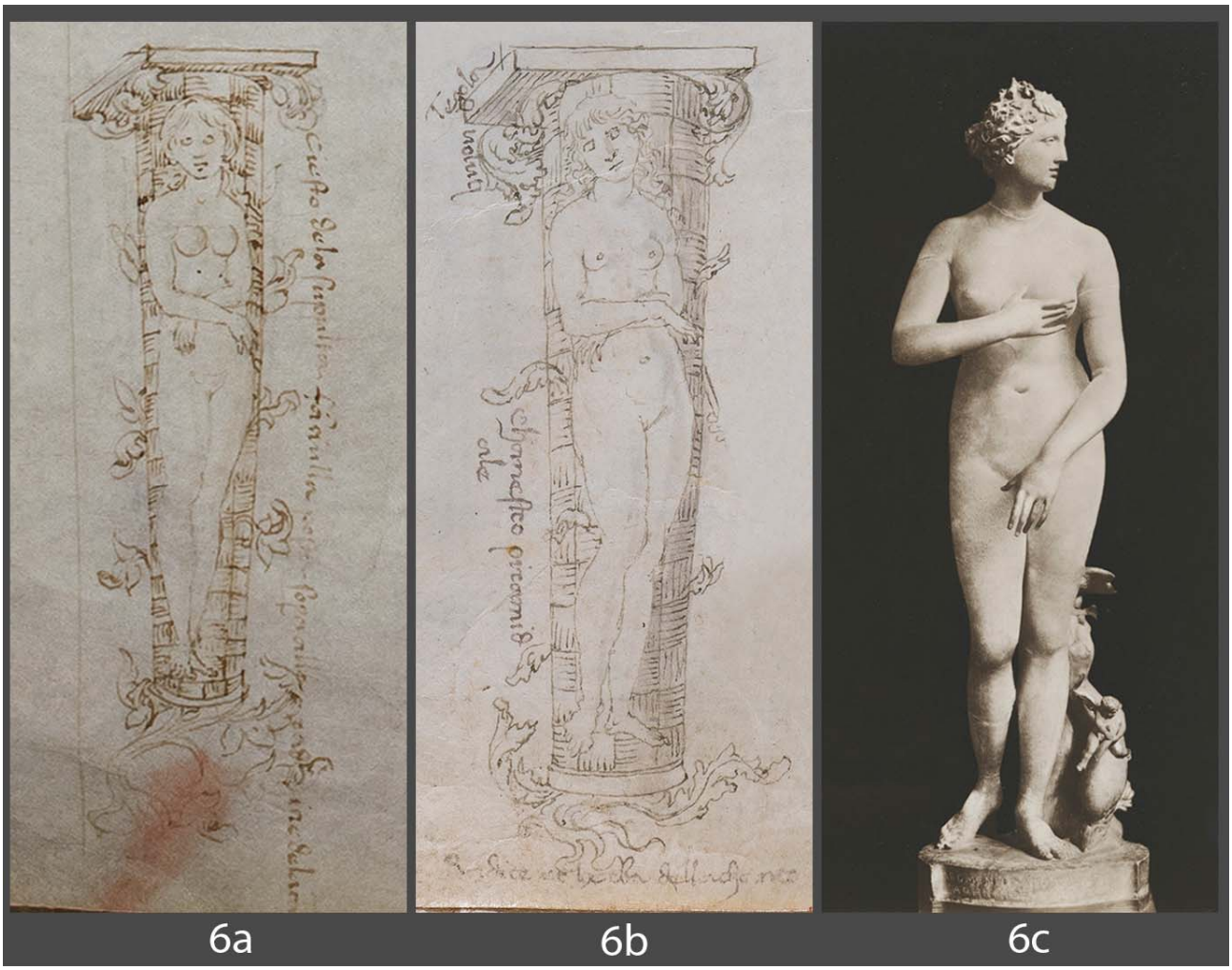

Fig. 6a: Enlarged-size image of the maiden from MS Ashb. 361. **Fig. 6b:** Enlarged-size image of the maiden from MS Saluzzo 148. Antonio Corso suggests that these drawings described Vitruvius, *De architectura* (IV, 1, 10) analytically may be inspired by the so-called Medici Venus presented in the following Fig. 6c. As highlighted by George Hersey (1998, 80, 83, figure 37), this rush basket drawing might have inspired one of the thirty monumental doors published by Sebastiano Serlio later in mid-sixteenth century (refer to Serlio, 1551, *Porte rustiche*, XX, in whose caption the author mentions that "in place of columns are herms dressed in woven rushes/*in luogo di colonne sono termini vestiti di gionchi tessuti*"). **Fig. 6c:** marble statue (height 1,53m) of a naked Aphrodite *anadyoméne* (ἀναδυομένη, i.e., rising up) from the sea with a dolphin, which has the same configuration of the statue that, according to the *Commentarii* by Lorenzo Ghiberti (3.56, ed. Morisani), had been discovered in Siena in the fourteenth century, with an ancient inscription declaring that the statue is a copy from a work of Lysippus. The subject of the statue had been declared *inhonestum* (i.e., inappropriate) and thus, following a public decree of the republic of Siena, dated 7 November 1357, the statue had been removed from the territory of Siena and placed in that of Florence. Probably it should be identified with the marble statue of naked Aphrodite with an arm brought near her breasts and another toward her pubes, which in the 1370s was kept in a house of Florence, where it had been seen by Benvenuto Rambaldi da Imola (*Comentum super Dantis Aldigherij Comœdiam*, Purgatorio, X, 32). In Florence, the statue, clearly brought from Siena without the base with the signature of Lysippus, was attributed to Polycleitus or Praxiteles. Ghiberti specifies that a drawing of this statue by Ambrogio Lorenzetti was available in Siena still in the 1440s (refer to Cittadini, 1997). The description of the Siena statue made by Lorenzo Ghiberti is corroborated Benvenuto Rambaldi da Imola. It seems to be a Medici-type Aphrodite because the dolphin near the leg was explicitly mentioned by Ghiberti and Benvenuto reports the posture of the arms of the statue. This type statuary derives from the Aphrodite of Sicione by Lysippus (refer to the coin published by Cittadini, 1997, 64, Figure 17), and is known from several Roman copies found in Italy whose most famous example is precisely so-called Venus de' Medici or Medici Venus. The commentary about this figure has been provided by Antonio Corso in November 2019. © Florence, *Galleria degli Uffizi* (refer to Mansuelli, 1958-1961, I, 71-73. The image comes from a postcard retrieved from Arstore via the online Library Services of Nanyang Technological University Singapore on 30 October 2020, URL: https://library.artstor.org/#/asset/SS35428_35428_39710260;prevRouteTS=1603366668192

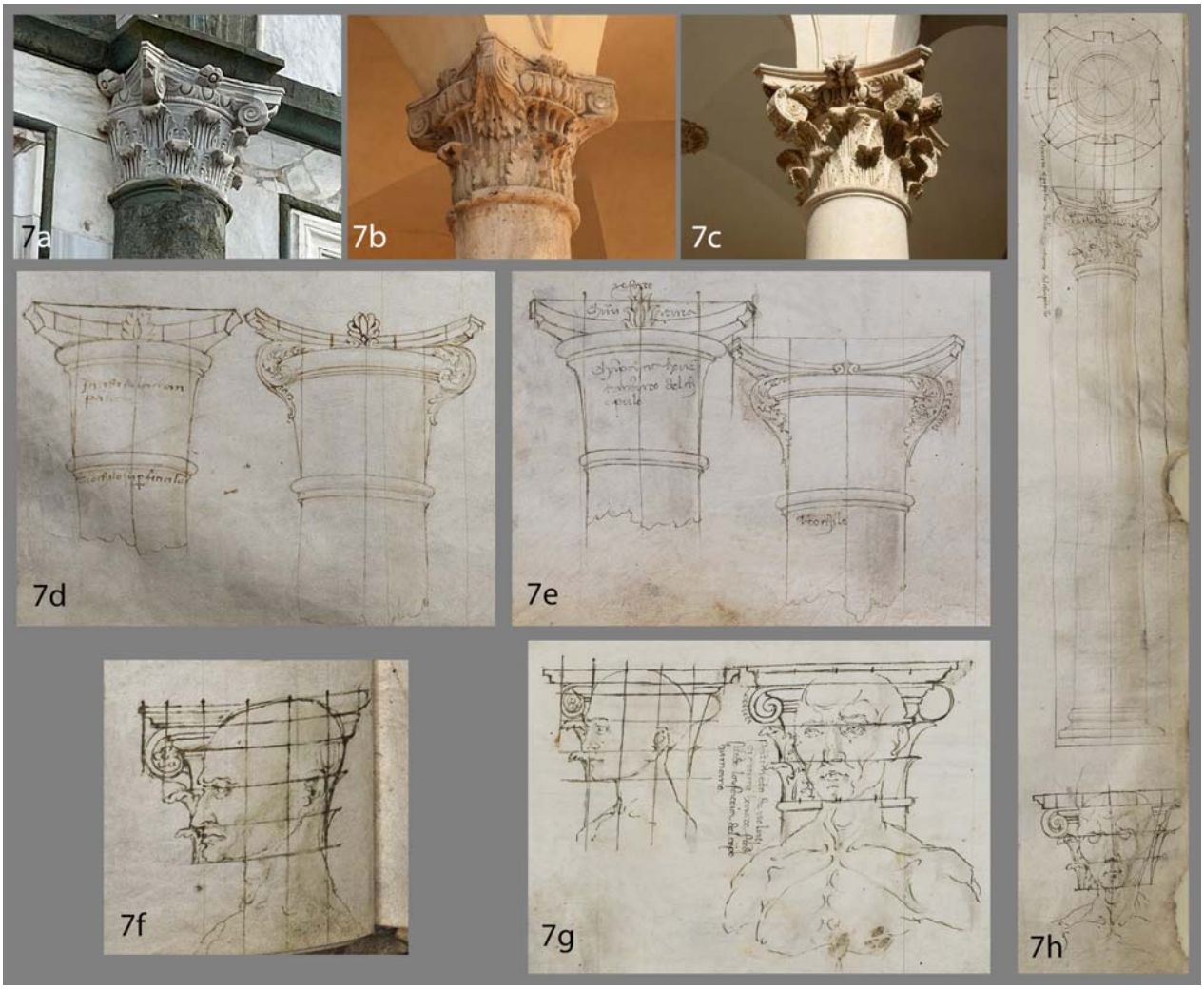

Fig. 7: Comparisons and associations between Martini's drawings, visual experiences, and construction sites related to the Corinthian/Composite capital. The capitals drawn in these manuscripts are not the exact visual representation of the Corinthian capital as described analytically by Vitruvius, *De architectura* (IV, 1, 11-12). Francesco di Giorgio Martini could have seen ancient Corinthian and Composite capitals in the places in which he was before and during the composition of *Trattato I* (refer to Fig. 1), not only in Tuscany (e.g., Siena, Florence), but also, for example, in Spoleto (Temple of Clitumnus) and Tivoli (Hadrian's Villa) as witnessed by the fragments of his sketchbooks (refer to Papini, 1946, I, 46, II, 16-29, 32-40, 42, 43). **Fig. 7a: Detail of a Composite capital from the façade of the *Basilica di San Miniato al Monte* (Florence, Italy).** Image retrieved on 30 October 2020 from the ArtStor web repository via the online Library Services of the Nanyang Technological Univerisity Singapore, URL: https://library.artstor.org/#/asset/SCALA_ARCHIVES_1039779756;prevRouteTS=1604122305890. **Fig. 7b: Detail of a Composite capital from the Cloister of Sixtus IV** dated 1474-1476 (by Baccio Pontelli, disciple and collaborator of Martini, refer to De Fiore, 1963; Fiore 2019; *Basilica di San Francesco*, Assisi, Italy). Photograph taken by Stefano Bertocci, with permission. **Fig. 7c: Detail of a Composite capital from the *Cortile del Palazzo Ducale di Urbino*** (Italy) dated 1478-1481 (designed by Martini, refer to Papini, 1946, I, 143-159, II, 145-151, III, Tav. XXVII). Photograph taken by Stefano Bertocci, with permission. **Fig. 7d:** Enlarged-size image of the **capitals** from MS Ashburnham 361, f. 13v (for a detailed description see Fig. 4a, 4b). **Fig. 7e:** Enlarged-size image of the **capitals** from and from MS Saluzzo 148, f. 14v (for a detailed description see Fig. 5a, 5b). **Fig. 7f: Capital with superimposed head (profile view)** from MS Ashburnham 361, f. 13v (for a detailed description see Fig. 4e). **Fig. 7g: Capitals with superimposed heads (profile and three-quarter views)** from MS Saluzzo 148, f. 15r. On the relationship between the capital (Greek κεφάλιον/*kephálion*, κεφαλίς/*kephalís*, head) and the human head in Vitruvius' *De Architectura* (III, 1, 2) and in Francesco di Giorgio Martini's *Trattato I*, refer to George Hersey (1998, 88). **Fig. 7h: Capital with superimposed head (three-quarter view)** associated with the above technical drawing of a full column (plan and front view, with caption *Missure e propo<r>zione della formazione del capitello*, "Measures and proportions of the formation of the capital"), from MS Ashburnham 361, f. 15r (N.B.: in MS Saluzzo 148, f. 16r, the drawing of the same column does not have the profile view off the head below, which is in f. 15r). In the drawings, horizontal and vertical lines show that the different mouldings of the order follow ideal proportions of the human head (chin-nose, nose-eyes, eyes-front). The capital and the head compose a modular grid to help the architect and give the 'correct' measures to the different parts of the capital.

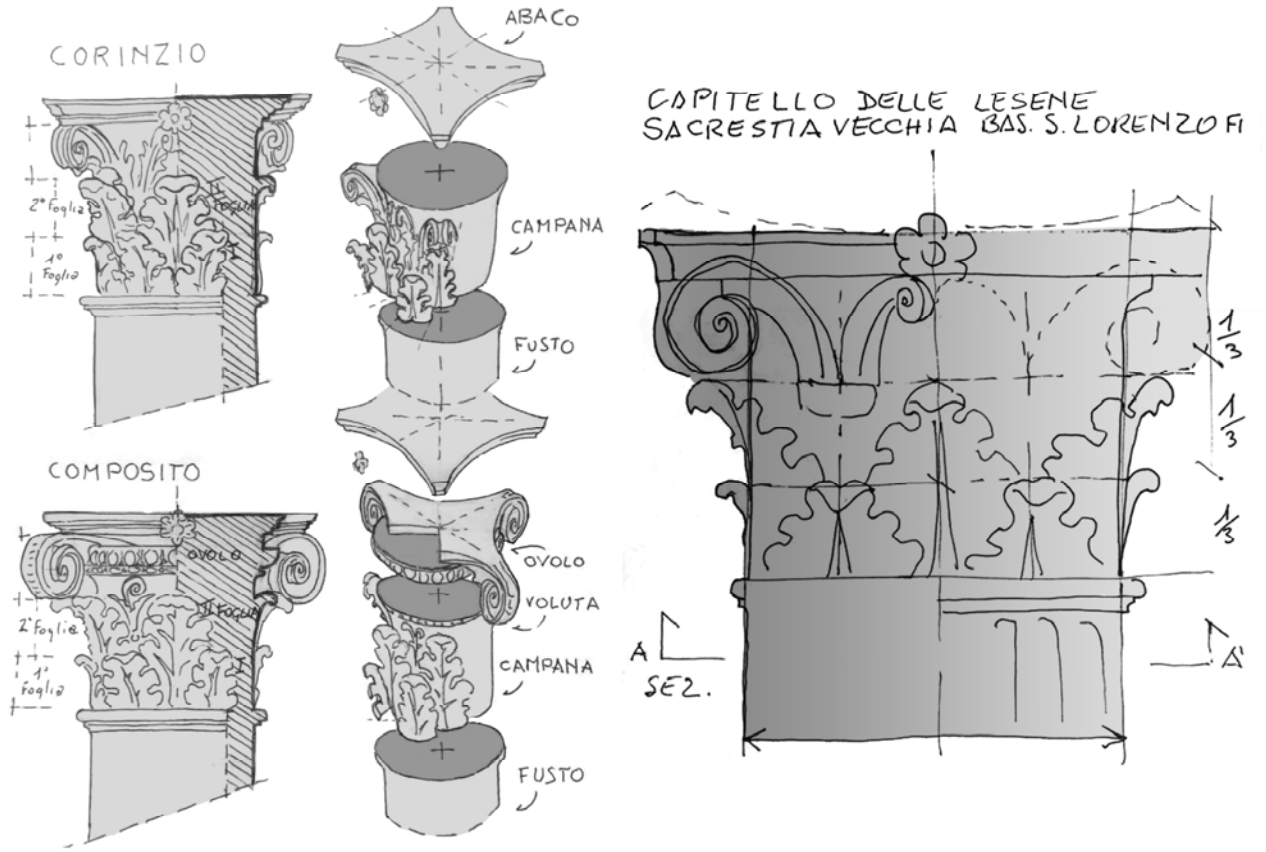

Fig. 8: Drawings for the interpretation of the decoration of the Corinthian and Composite capital by Stefano Bertocci that has been used as a base to decompose the volumes for the 3D modelling. Francesco di Giorgio Martini, in line with the fifteenth-century literature, depicts capitals that will be called Composite in the sixteenth-century treatises on architecture (refer to Serlio, 1537, vi, for the five orders; Ch. VIII, Corinthian Order; Ch. IX, Composite Order).

3. *Creating philologically correct 3D models, decoding their embedded narratives, and connecting knowledge via EHM*

To create a philologically correct 3D model of this capital, the authors applied the method (i.e., systematic procedure) developed and tested by Andrea Nanetti and Davide Benvenuti to generate 3D animated visualisations able to improve upon 2D visualisation methods of the ships depicted on the Fra Mauro's map of the world (Nanetti, & Benvenuti, 2019, 37-41).

This method—which took into consideration the most recent best practices in the field of digital representation of historical architectural elements (e.g., De Paoli, & Capone, 2015; Luo et al., 2018; Piñero Vega et al., 2019; Valzano, Negro, & Lucarella, 2019)—was designed to create 3D models able to visualise different sets of information embedded in drawings and stimulate the discussion without inferring any final interpretation of the picture itself.

However, as demonstrated in Section 2, Martini's drawings have further elements of complexity. They reflected information retrieved from both classical texts and ancient architectures and served as theoretical foundation for real artefacts that he realised in his construction sites (Fig. 7). As a starting point to investigate this series of relationships visually, the authors chose one drawing of a capital depicted in MS Ashb. 361 (Fig. 4b) and explored it through the following consequential series of complementary 3D models and animations.

1) Visual translation of Vitruvius' narrative of the origin of the Corinthian capital (*De Architectura* (IV, 1, 9; refer to the commentary here above in Section 2) to be used as a preliminary and tentative template.

2) Visualisation of the decomposition of the basic volumes of ideal Corinthian and Composite capitals (Fig. 8) to be used as preliminary and tentative templates.

3) Non-Photorealistic Rendering (NPR) of the drawing as it is depicted in MSS Ashb. 361 (f. 13v; Fig. 4b) and Sal. 148 (f. 14v; Fig. 5b).

4) Visual translation of the proportions of the ideal Corinthian capital as described in Vitruvius' *De Architectura* (IV, 1, 11-12) and translated into Vernacular Italian by Martini in *Trattato I* (Ch. LII).

5) Photo-realistic visualisation of still-existing Corinthian capitals on which Vitruvius possibly based his description (e.g., late-fourth-century-BC Corinthian capitals of the Skopas-temple in Tegea, temple of Zeus in Nemea, Peloponnese, Greece).

6) Photo-realistic visualisation of still-existing sets of ancient capitals available in the *Basilica di San Miniato al Monte* (Florence; see Section 2).

7) Photo-realistic visualisation of still-existing sets of capitals available from Martini's construction sites dated to the same period of *Trattato I* (e.g., *Cortile del Palazzo Ducale di Urbino*, refer to Papini, 1946, II, 145-151, III, Tav. XXVII, *Cortile del Palazzo Ducale di Gubbio*, Papini, II, 118-120).

7) Photo-realistic visualisation of still-existing sets of capitals available from construction sistes of Martini's disciples and collaborators (e.g., Cloister of Sixtus IV dated 1474-1476 and made by Baccio Pontelli's Cloister of Sixtus IV dated 1474-1476 in *Basilica di San Francesco*, Assisi, Italy; Fig. 7b).

8) Finally, a short-format animated film, which can be construed as a video knowledge aggregator, shows all the information about the Corinthian capital investigated by the research team (see storyboard in Fig. 10).

Each of the above products is available on the website of the Engineering Historical Memory (EHM) project, where the user can explore the earliest copies of Martini's *Trattato I* (MSS Ashb. 361 and Sal. 148) and its related scholarship, activate the 3D objects, aggregate relevant secondary resources (publications, images, videos, and news) in real-time, and save the results on a personalised notebook.

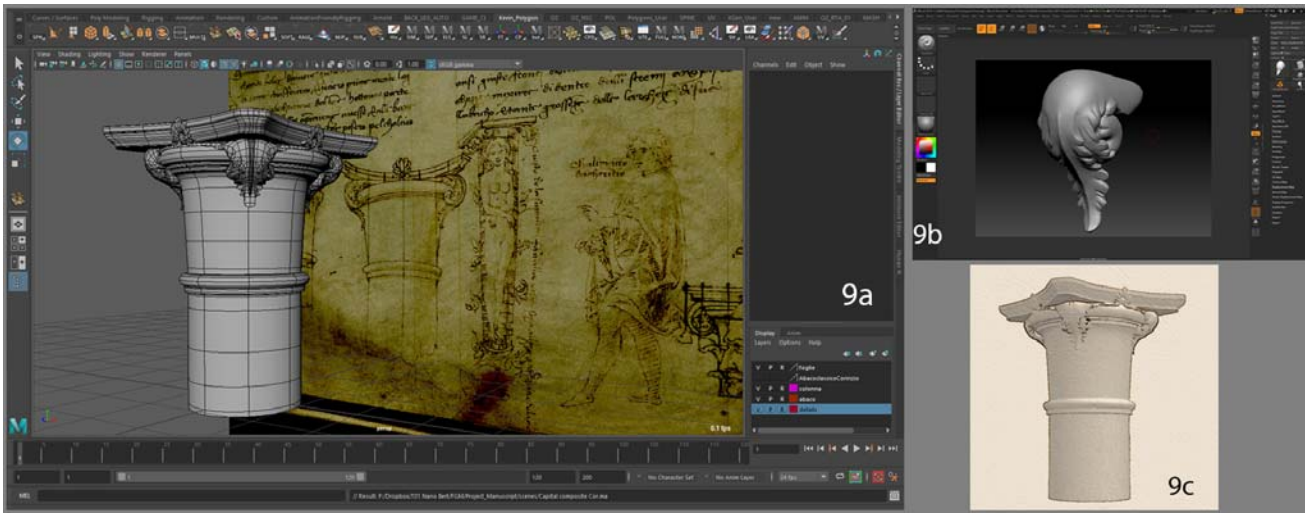

Fig. 9a: Screenshot of the Autodesk® Maya® Viewport 2.0 interface showing the 3D geometry and topology of the assembled Corinthian capital with all the basic volumes as drawn in MS Ashb. 361, f. 13v (refer to Fig. 4b). **Fig. 9b**: Screenshot of the Pixologic® ZBrush® interface with the image of the 3D model that interprets the acanthus leave on the top-left of Fig.4b. **Fig. 9c**: Screenshot of the Autodesk® Maya® Viewport 2.0 render showing at work the Maya Non-Photorealistic Rendering (MNPR) plug-in developed by Santiago Montesdeoca (Montesdeoca, 2018, 131-140), which, here, is applied to the model in an early iteration to simulate a 3D interpretation of the Fig. 4b.

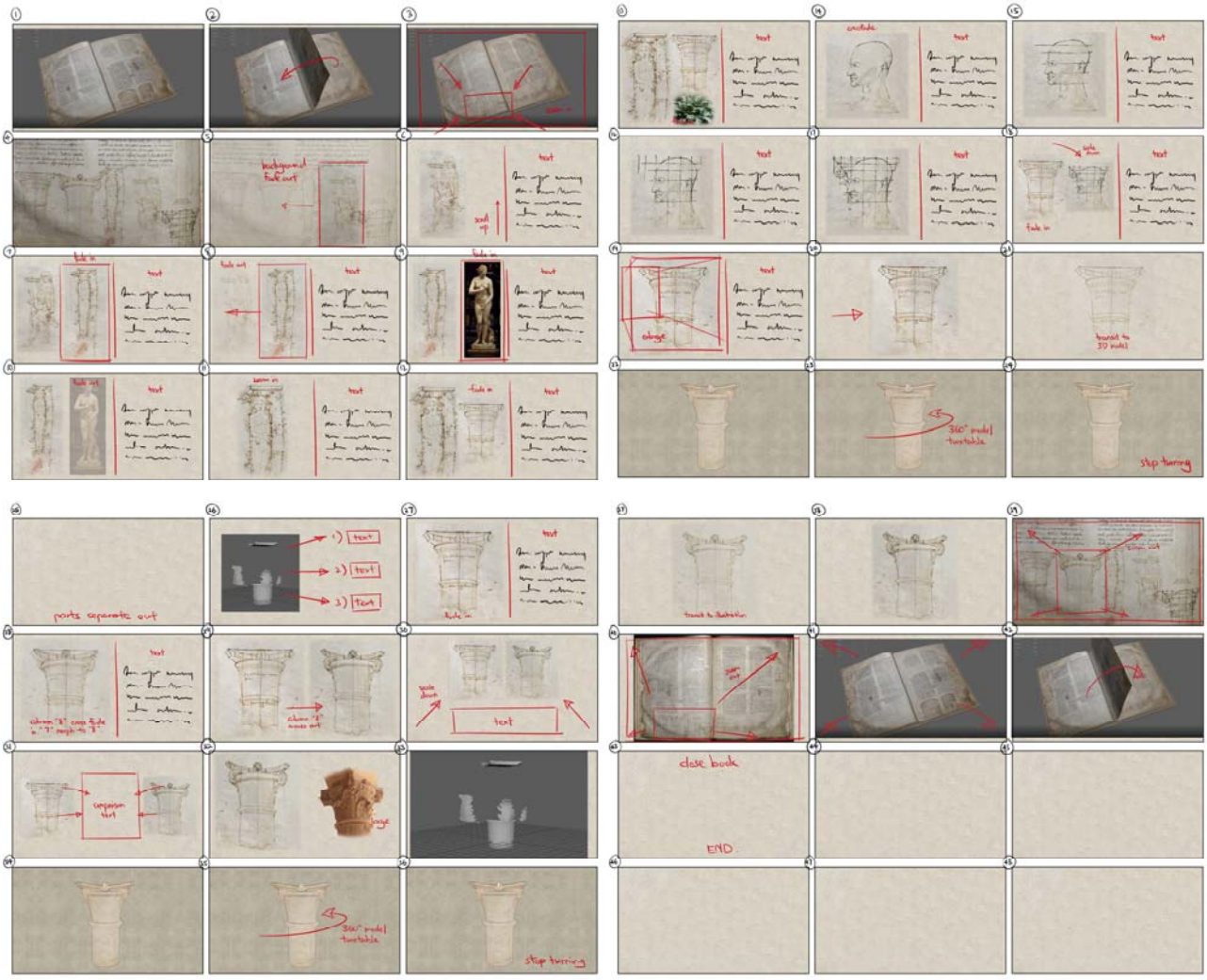

Fig. 10: Storyboard that aggregates information about the Corinthian capital collected by the research team from heterogenous sources, such as the drawings of MS Ashb. 361, f. 13v (Fig. 4), some still-existing artefacts available to Martini (Figg. 6c, 7a), designed by Martini and his collaborators (Figg. 7b, 7c), and the text of Vitruvius' *De architectura* (IV, 1, 10).

4. Conclusions

For the modelling of the volumes of the Corinthian capital, the research team collected, analysed, and compared different sources of information (texts, drawings, monuments) with philological, art historical, and animation methods visually. The results of this research have been shared in the present paper and merged into digital products available online in the interactive system Engineering Historical Memory (EHM).

In EHM, these digital objects are empowered by the EHM search tool, which automatically links them to relevant secondary sources of information (scholarly publications, images, videos, and news) in real-time. The EHM system is also a tool to automatically trace the provenance and validate the information aggregated in the digital products.

Since its initial stages, the research highlighted that the drawings could not be construed as a simple visual interpretation of Martini's translation into Vernacular Italian of Vitruvius' excerpts. Thus, to map and decode the visual information and knowledge embedded in the drawings, the authors undertook an investigation on what Martini might have absorbed from both monuments available in the places in which he lived and visited, and the

experience of the construction sites in which he was involved.

The 3D visualisation of the drawings related to the Corinthian capital in two of the earliest copies of Francesco di Giorgio Martini's *Trattato I* (MS Ashburham 361, Fig. 2; MS Saluzzo 148, Fig. 3) demonstrated that digital animation could be an effective tool to visually investigate and reverse engineer their creative process and produce philologically correct 3D models of the depicted objects. This kind of objects can not only be displayed in different creative platforms but also contribute to the advancement of learning in the study of Renaissance treatise on civil and military architecture.

The interdisciplinary method described in this paper can be adopted by both scholars in the humanities and practitioners in animation to map and decode the knowledge embedded in drawings depicted not only in Renaissance treatises on architecture but in science, technology, and medicine manuscripts at large.

Acknowledgements

The authors undertook the research presented in this paper between November 2019 and September 2020. The Francesco di Giorgio Martini Online is an ongoing interdisciplinary research project carried out by Andrea Nanetti (history) and Davide Benvenuti (animation) at Nanyang Technological University (NTU) Singapore and by Stefano Bertocci and Matteo Bigongiari (architecture) at the *Università degli Studi di Firenze* (UNIFI) since 2019 within the framework of a Research Collaboration Agreement retroactively signed between the parties (NTU and UNIFI) on 30 October 2020. The research project is supported by the Ministry of Education, Singapore, under its Academic Research Fund Tier 1 (PI Andrea Nanetti, Co-PI Davide Benvenuti, 2019-2022, RG45/19NS) and by the DIDALABS of UNIFI (PI Stefano Bertocci).

The digital photographs of MS Ashb. 361 have been taken by Matteo Bigongiari and used with permission of the *Biblioteca Medicea Laurenziana* of Florence ("su concessione del Ministero dei beni e delle attività culturali e del turismo, MiBACT - BML - Prot. 2789/28.13.10.01/2.29"). The digital photographs of MS Saluzzo 148 have been provided by and are used with permission of the *Musei Reali* of Turin ("Convenzione, 6 ottobre 2020"). The digital photographs of MSS Reggiani A 46/9 bis have been taken by the photographer Carlo Vannini (Reggio Emilia) and used with permission of the *Biblioteca Comunale «Antonio Panizzi»* of Reggio Emilia ("concessione a titolo non oneroso delle immagini del frammento, 16 April 2020"). The digital photographs of MS Magliabechiano II.I.141 are used with permission of the *Biblioteca Nazionale Centrale* of Florence ("su concessione del Ministero dei beni e delle attività culturali e del turismo / Biblioteca Nazionale Centrale di Firenze, 31 luglio 2020").

The NTU students Clemens Tan Yu Chen and Oen Weng Wah worked as Student Training Assistants (Supervision, Davide Benvenuti) on 3D modelling funded by the above-mentioned Tier 1 (RG45/19NS) in March-April 2020. The NTU students Oen Weng Wah Nicholas and Teo Jing Yi undertook an internship funded by UNIFI (Supervision, Stefano Bertocci) and worked on 3D modelling in May-August 2020.

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This research is set in the framework of the Engineering Historical Memory (EHM) project. Andrea Nanetti first theorized EHM as a Visiting Scholar at Princeton University in 2007 to explore Digital Humanities. From 2012 to 2014 the project was on WordPress. Since 2015 it is on Microsoft Azure. In 2018, Ker Min Jie curated a first redesign of EHM from a Computer Science perspective as Final Year Project for the bachelor's degree in computer science at NTU (Principal supervisor Gao Cong, Co-Supervisor Andrea Nanetti). Since March 2019, Khoi Nguyen Vu is Research Assistant to the project for web development funded by the Ministry of Education, Singapore (Tier 1 RG55/17NS and RG45/19NS).

REFERENCES

Baldinucci, F. (1681). *Vocabolario Toscano dell'Arte e del Disegno*. Firenze: Per Santi Franchi al Segno della Passione. Digital edition, retrieved on October 30, 2020, from http://baldinucci.sns.it/html/index.html

Barnes, C. F. Jr. (2009). The Portfolio of Villard de Honnecourt (Paris, Bibliothèque nationale de France, MS Fr 19093): A New Critical Edition and Color Facsimile. Abingdon: Routledge.

Bartoli, A. (1914). I monumenti antichi di Roma nei disegni degli Uffizi di Firenze. Rome: C. A. Bontempelli.

Beck, J. H. (1969). M. Taccola, *Liber tertius de ingeneis ac edifitiis non usitatis*. Milan: Il Polifilo.

Beltramini, M. (2001). Le illustrazioni del *Trattato d'architettura* di Filarete: storia, analisi e fortuna. *Annali di Architettura*, 13, 25-52.

Bertocci, S., Pivetta, M., & Bigongiari, M. (2019). The Ashburnham 361 codex: Digital survey of the treatise on civil and militar architecture by Francesco di Giorgio Martini with the notes of Leonardo da Vinci. In P. Belardi (Ed.), *Reflections. The art of drawing/ the drawing of art* (pp. 359-364). Roma: Gangemi.

Biffi, M. (1997). Una proposta di ordinamento del testo di architettura del Codice Zichy. Le origini della produzione teorica di Francesco di Giorgio Martini. *Annali Della Scuola Normale Superiore di Pisa. Classe di Lettere e Filosofia*, 2(2), 531-600.

Birkenmajer, A. (1932). Zur Lebensgeschichte und wissenschaftlichen Tätigkeit von Giovanni Fontana (1395?-1455?). *Isis*, 17(1): 34-53.

Borsi, S. (1985). *Giuliano da Sangallo: I disegni di architettura e dell'antico*. Roma: Officina.

Bruschi, A. (1998). Brunelleschi e la nuova architettura fiorentina. In F. P. Fiore (Ed.), *Storia dell'architettura italiana. [2] Il Quattrocento* (pp. 38-113). Milan: Electa.

Bruschi, A., Pacioli, L., Colonna, F., & Leonardo. (1978). *Scritti rinascimentali di architettura*. Milan: Il Polifilo.

Burns, H (1994). I disegni di Francesco di Giorgio agli Uffizi di Firenze. In Fiore, F. P., & Tafuri, M. (Eds.), *Francesco di Giorgio Architetto* (pp. 330–357). Milan: Electa.

Cittadini, R. (1998). Figure femminili di Lisippo. *Bollettino d'arte / Ministero Per i Beni e le Attività Culturali, Direzione Generale per il Patrimonio Storico, Artistico e Demoetnoantropologico*, 6, 55-80.

Corso, A. (2005). 'De Virginum poculis': Considerazioni su Vitruvio 4, 1, 9. *Materiali e Discussioni per l'analisi dei Testi Classici,* 55, 193-203.

Corso, A., Romano, E., & Gros, P. (1997). *Vitruvio, De architectura*. 2 vols. Turin: Einaudi.

De Fiore, G. (1963). *Baccio Pontelli, architetto fiorentino*. Rome: Edizioni dell'Ateneo.

De Paoli, M., & Capone, A. (2015). New methods to survey and represent the classical architecture: the Rosario's altar of Beata Paola's chapel in Volta Mantovana. *DisegnareCon*, 8/14, 1-19.

Fiore, F. P. (1978). *Città e macchine del '400 nei disegni di Francesco di Giorgio Martini*. Florence: L. S. Olschki.

Fiore, F. P. (2019). *Architettura e arte militare, mura e bastioni nella cultura del Rinascimento.* Rome, Campisano Editore.

Galluzzi, P. (1991). Le macchine senesi: Ricerca antiquaria, spirito di innovazione e cultura del territorio. In P. Galluzzi (Ed.), *Prima di Leonardo. Cultura e macchine a Siena nel Rinascimento* (pp. 15-44). Milan: Electa.

Giardini Pedro, A. P. (2011). *A ideia de ordem:* symmetria *e* decor *nos tratados de Filarete, Francesco di Giorgio e Cesare Cesarino*. Tese (Doutorado – Área de Concentração: Projeto, Espaço e Cultura). São Paulo: FAUUSP.

Giuliano, A. (1994). Vitruvio e l'acanto. *Palladio*, 14, 29-36.

Gurrieri, F., Berti, L., & Leonardi, C. (1988). *La basilica di San Miniato al Monte a Firenze*. Florence: Giunti.

Hersey, G. (1988). *The Lost Meaning of Classical Architecture: Speculations on Ornament from Vitruvius to Venturi*. Cambridge, MA: MIT Press. Translation into Italian: Hersey, G. L. (2001).

Jones, M. (1991). Designing the Roman Corinthian Capital. *Papers of the British School at Rome*, 59, 89-150.

Krohn, F. (1912). *Vitruvius Pollio. On Architecture*. Leipzig: B. G. Teubner.

Luo, S. S., Shedd, B. A., & Nanetti, A. (2018). Enhancing the Experience of the Western Xia Imperial Tombs Heritage Site (PRC, Ningxia) through Animated Installations. *SCIRES-IT - SCIentific RESearch and Information Technology*, 8(1), 1-32. http://dx.doi.org/10.2423/i22394303v8n1p1

Maltese, C., & Maltese Degrassi L. (1967). *Trattati di architettura, ingegneria e arte militare*. Milan: Il Polifilo.

Mansuelli, G. (1958-1961). *Galleria degli Uffizi: Le Sculture*. 2 vols. Rome: Istituto Poligrafico dello Stato.

Marani, P., & Mussini, M. (1979 & 1994). *Trattato di architettura di Francesco di Giorgio Martini. Il codice Ashburham 361 della Biblioteca Medicea Laurenziana di Firenze*. 3 vols., with facsimile edition. Florence: Giunti Barbera.

Martini, F. G. (2002). *La traduzione del "De architectura" di Vitruvio. Dal m. II. I.141 della Biblioteca Nazionale Centrale di Firenze*. Pisa: Scuola Normale Superiore.

Merrill, E. M. (2013). The *Trattato* as Textbook: Francesco di Giorgio's Vision for the Renaissance Architect. *Architectural Histories*, 1(1), Art. 20. DOI: http://doi.org/10.5334/ah.at

Migliari, R. (1991). Il disegno degli ordini e il rilievo dell'architettura classica: 5 pezzi facili. *Disegnare Idee Immagini*, 2, 49-66.

Mussini, M. (1991). *Il "Trattato" di Francesco di Giorgio Martini e Leonardo: Il Codice Estense restituito*. Parma: Università di Parma. Istituto di storia dell'arte.

Nanetti, A. (2020). *Engineering Historical Memory*. Retrieved on October 30, 2020, from https://engineeringhistoricalmemory.com/About.php

Nanetti, A., & Benvenuti, D. (2019). Animation of two-dimensional pictorial works into multipurpose three-dimensional objects. The Atlas of the Ships of the Known World depicted in the 1460 Fra Mauro's Mappa Mundi as a showcase. *SCIRES-IT - SCIentific RESearch and Information Technology*, 9(2), 29-46. http://dx.doi.org/10.2423/i22394303v9n2p29

Papini, R. (1946). *Francesco di Giorgio architetto*. 3 vols. Florence: Electa Editrice.

Payne, A. A. (1999). *The Architectural Treatise in the Italian Renaissance: Architectural Invention, Ornament, and Literary Culture*. Cambridge: Cambridge University Press.

Piñero Vega, D., Valerga, A. P., Ordoñez Orellana, F. A., & Batista, M. (2019). Application of Computer Aided Design and Additive Manufacturing to the recovery of the Paddle Boat by Francesco Di Giorgio. *Procedia Manufacturing*, 41, 1119-1126.

Prager, F. D., & Scaglia, G. (1972). *Mariano Taccola and his book 'De ingeneis'*. Cambridge, MA: MIT Press.

Promis, C., & Saluzzo, C. (1841). *Trattato di architettura civile e militare di Francesco di Giorgio Martini architetto senese del secolo XV*. Turin: Tipografia Chirio e Mina.

Ridley, R. T. (1989). The Fate of an Architect: Apollodorus of Damascus. *Athenaeum*, 67, 551-565.

Scaglia, G. (1971). M. Taccola, *'De machinis': The engineering treatise of 1449*. Wiesbaden: Ludwig Reichert.

Scaglia, G. (1991). Francesco di Giorgio, autore. In P. Galluzzi (Ed.), *Prima di Leonardo. Cultura delle macchine a Siena e nel Rinascimento* (pp. 57-80). Milan: Electa.

Scahill, D. (2009). The Origins of the Corinthian Capital. In R. V. Hoff, & P. Schultz (Eds.), *Structure, Image, Ornament: Architectural Sculpture in the Greek World* (pp. 40-53). Oxford: Oxbow Books.

Serlio, S. (1537). *Regole generali di architetura sopra le cinque maniere de gli edifici, cioè, Thoscano, Dorico, Ionico, Corinthio, et Composito, con gli essempi dell'antiquità, che per la magior parte concordano con la dottrina di Vitruvio*. Venice: Per Francesco Marcolini da Forlì. Later, published in Idem (1584), *I sette libri dell'architettura* (Book IV). Venice: Appresso Giovan Battista et Marchio Sessa Fratelli.

Serlio, S. (1551). *Extraordinario libro di architettura di Sebastiano Serlio architetto del re christianissimo: Nel quale si dimostrano trenta porte di opera rustica mista con diversi ordini: & venti di opera dilicata di diverse specie con la scrittura davanti, che narra il tutto*. Lyons: Per Giovan di Tournes.

Settia, A. (2004). Guido da Vigevano. *Dizionario Biografico degli Italiani*, 61.

Shelby, L. R. (1975). Mariano Taccola and His Books on Engines and Machines. *Technology and Culture*, 16(3), 466-475.

Shute, J. (1563). *The first and chief groundes of architecture used in all the auncient and famous monymentes*. London: T. Marshe.

Sparavigna, A. C. (2013). Giovanni de la Fontana, engineer and magician. Retrieved on October 30, 2020, from Cornell University Library at https://arxiv.org/pdf/1304.4588.pdf

Swetz, F. J. (2008). Leonardo da Vinci's Geometric Sketches - Cylinder and Cone. *Convergence*. Retrieved on October 30, 2020, from DOI: 10.4169/loci002559

Tapinassi, C. (2016). *La trattatistica di architettura del Quattrocento. I disegni di Francesco di Giorgio Martini nel codice Ashburnham 361 della Biblioteca Medicea Laurenziana di Firenze*. Tesi di Laurea. Corso di Laurea in Storia e Tutela dei Beni Culturali della Scuola di Studi Umanistici e della Formazione dell'Università degli Studi di Firenze.

Valturio, R. (1472). *De re militari [On the military arts]*. Verona: Johannes ex Verona.

Valzano, V., Negro, F., & Lucarella, D. (2019). Otranto Treasures in 3D. *SCIRES-IT - SCIentific RESearch and Information Technology*, 9(2), 17-28. http://dx.doi.org/10.2423/i22394303v9n2p17

Vecce, C. (2017). *La biblioteca perduta. I libri di Leonardo*. Rome: Salerno Editore.

Vitruvius the Ten Books on Architecture (1914), Translated by Morris Hicky Morgan. Cambridge, MA: Harvard University Press.