The Palazzo del Podestà in Bologna: Precision and Tolerance in a Building *all'Antica*

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Mario Carpo has shown how to map out a parallel history of Renaissance architecture and numeracy through the study of treaties and theory.[1] He also suggests that such results are much more difficult to obtain when examining built works. Existing architectural drawings, especially those from fifteenth-century Italy, are scarce, as are accurate surveys and written construction documents.

In light of these obstacles, historians may usefully consider the evidence of the buildings themselves. The Palazzo del Podestà in Bologna offers an important case study for some of the quantitative and numeric features of built architecture of the last quarter of the fifteenth century. It shows, in particular, how imperfections in construction and difficult site conditions could hinder the much-desired ideal of geometrical, mathematical, and proportional exactitude that was already well diffused in both the theory and practice of Renaissance architecture.[2] The Palazzo, a project of the early 1470s, can serve as a model for understanding how the idea of a building conceived on the model of the geometric grid—with precisely calculated, exact, and whole measurements—was the strongest prerogative of the well-educated Renaissance architect (Fig. 1).[3] Such characteristics imply a knowledge of precise geometrical and mathematical rules, the ability to render meticulous and accurate drawings, and to execute them in built form. It also reflects the capabilities of stonemasons to create architectural elements of great precision.

The Palazzo del Podestà illuminates how architects reconciled a desire for geometrical accuracy and modularity—an ideal condition of simplicity but also a necessity for building a portico *all'antica*—with the irregularities inherent in a pre-existing medieval site and the need to fully exploit the existing foundations. The building reveals, in particular, how careful attention to minute differences between architectural elements helped the designer to form an analyzable, modular, and geometrically

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Fig. 1 Palazzo del Podestà, Bologna

quantifiable "exact" space. The use of such optical refinements, in particular, was precocious. The technique was in principle known only through the obscure and still poorly known writings of Vitruvius and the treatise of Leon Battista Alberti, both of which were at that time still available only in manuscript form.[4] Finally, the Palazzo suggests that dimensional exactitude and repeatability were important not only for the composition of a building but also for reasons of cost and efficiency.

Correcting Irregularities

On 9 November 1472, the *Comune* of Bologna commissioned a model that would determine the basic volumetric features and architectural elements of the new *Palazzo Comunale*. The project was intended to utilize the existing foundations and walls of a previous medieval building constructed, along with the related piazza, in 1200–1203.[5]

While the document does not mention the architect in charge, we can attribute the work, for various reasons, to the illustrious Bolognese engineer Aristotele Fioravanti.[6] Aristotele—his name itself expresses, not by chance, a connection with geometry—was already known both throughout the Italian peninsula and abroad for his engineering endeavors. These began in 1451–1452 with the excavation and transportation of giant monolithic roman columns from the area of the church of Santa Maria sopra Minerva in Rome to the Vatican, to be employed in the choir of the new Basilica.[7] In 1455, he successfully transported Bologna's tower of the Magione 13 m

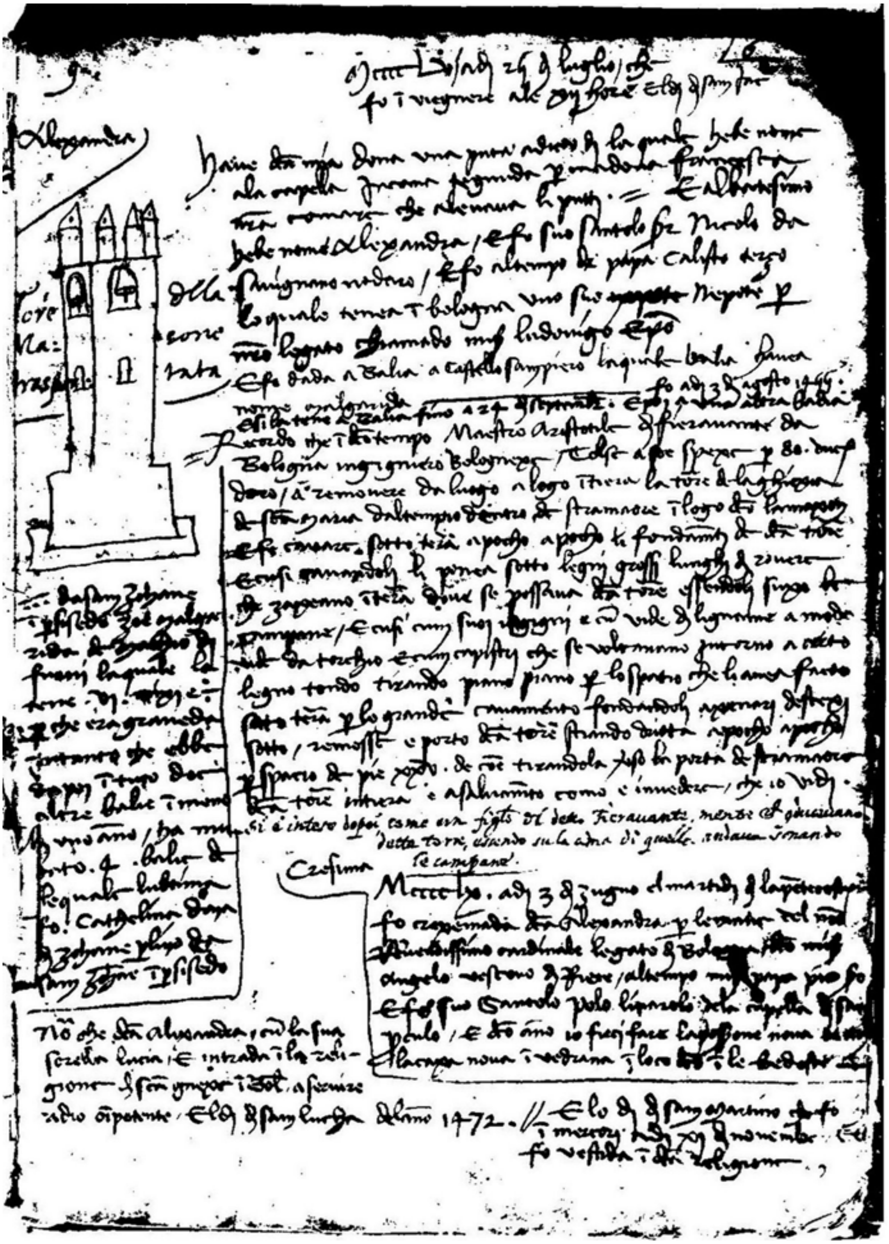


Fig. 2 Tower of the Magione, Bologna, Biblioteca Archiginnasio

to the opposite side of Strada maggiore (Fig. 2), a feat for which he gained considerable fame and enough work to keep him busy under three papacies and at several Italian and foreign courts, some as far away as Hungary and Russia.[8] Fioravanti's renown must also have brought him the commission for the Palazzo del Podestà, but

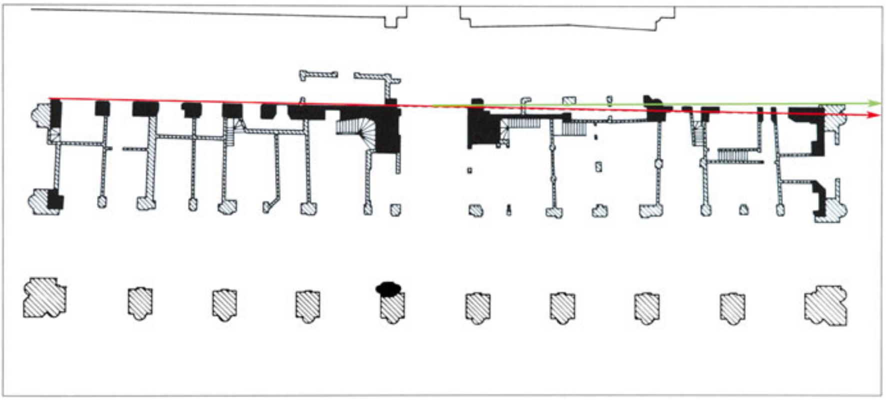


Fig. 3 Measured ground plan of the Palazzo del Podestà

he did not oversee the reconstruction. By 1484, when work began on the site, he had already died, probably during a trip to Siberia.[9]

The primary goal of the project was to obtain a series of arches around the pre-existing medieval envelope of the building that were as similar as possible to one another and that presented the greatest rhythmic, proportional, and modular coherence.[10] The end result is visible in a modern, measured survey of the building, which also makes clear the relationship between the earlier building and later additions (Fig. 3).[11] The footprint of the Renaissance arcade running around the perimeter is indicated with hatching, while the earlier medieval structure is marked in black on the plan. This structure consisted principally of a massive rear wall running east-west and divided into narrow shops. This long wall was capped on its extremities by two perpendicular end walls, and it was pierced by a passageway on axis with the central arch. The passageway, centered on the intersection of a minor Roman road to the rear of the Palazzo, contained the foundations of the bell tower.[12] Another given established by the earlier building—which is not visible on this plan—was the height of the floor of the great hall—the *sala magna*—on the second story.[13]

These pre-existing elements—particularly the perpendicular sections on either end of the medieval wall—determined the building's basic proportional schema. The two terminal walls established both the depth of the internal shops and the inner boundary line of the arcaded loggia. These elements had to remain fixed in order to respect the cross axis of the central passage and the piazza on the exterior. Those medieval end walls would also determine the general width of the bays to be used throughout the façade.

Considering the desire for precise regularity in the arcade, the pre-existing condition of the site presented several problems. The first was that the bays defined by the terminal walls of the medieval structure were not compatible with the length of the façade, being slightly too broad to provide even multiples that could be contained within its length. More importantly, the two ends were themselves of different width. As is shown on the plan, the line of the Palazzo's rear medieval wall followed the slightly crooked outline of the roman road to the rear of the structure. This road deviated 1.5° to the north from the base of the bell tower at the center of our building, creating an extra 60 cm on the eastern side. The deviation is shown by the red and green arrows on the plan. The result of these slight discrepancies was that the perimeter of the building, far from being regular in form, embodied an axial incongruity that made the site incompatible with the demands of regular bays *all'antica* with pillars, engaged columns and arches.

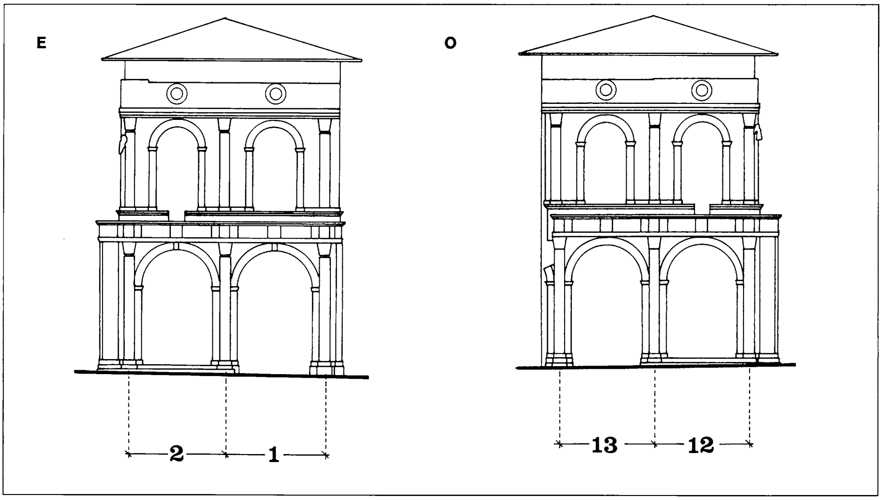
A survey of the building's elevations reveals the intriguing solution to this problem (Table 1, Fig. 4). In confronting it, Fioravanti—or his builder—created subtle differences in the width of the front and side bays that are invisible to the naked eye. Discrepancies are normal to certain extent—especially in porticoes. In a Renaissance building like this one, a normal construction "tolerance"—that is, the inaccuracy inherent in contemporary building methods—would be within 5 or 6 cm for every 700. The difference of 5 cm between the two corner bays of the front façade, for example, is relatively negligible and therefore we can consider them to be equal. However, in other parts of the building, the measurements diverge by as much as 61 cm. Bay 8—the narrowest in the building—differs from bay 1 by this amount, or just under two Bolognese feet.[14] Such an easily measured and evenly quantified irregularity—which corresponds incidentally to the length of two Bolognese bricks—rules out the possibility that the discrepancy was simply within the normal "tolerance" of early Renaissance builders.[15]

To solve the first problem, the lateral arcades were made to fit a subtly different dimensional scheme that that of the façade. The side bays, in other words, are on average 20 cm wider than those on the long façade. It is a very slight difference of less that 3 %, but nonetheless an important one. The second problem—the long wall section caused by the crooked road—was solved in a similar way. To compensate for the additional length, the architect widened the corresponding bay by 33 cm more than its counterpart on the opposite end. Of the lateral bays, only this one is perceptibly bigger. The other three vary within a difference of at most 6 cm. The module chosen for the short ends of the building is therefore based on the opposite bay (13) on the west. This solution, however, necessitated another irregularity. Because they were restricted by the railed architrave above, the lateral arches, particularly those of the longer bay (1) are actually squashed. The height of the ground story could not be greatly altered in order to keep the hall on the same level with the *iter in voltis*, a terraced path leading from the rear to other buildings in the complex (Figs. 5 and 6).[16] This deformation, however, is too slight to be visually perceptible. It has only come to light through our measured survey.

Table 1 Dimensions in the facade of the Palazzo del Podestà, Bologna (to be read with Fig. 4)

	1	2	3	4	5	6	7	8	9	10	11	12	13
A	734	707	681	681	680	680	673.5	673	682	680	682	702	701
B	525	514	480	483	480	486	476	475	482	481	481	507	495
C	320.5	304	282.5	295	300	304	292.5	299.5	300	300	307	307	312
D	736	706	671	681	698.25	684	668.5	677.5	677.25	680	687.5	703.5	728.5
s	115	114	104.5	99	102.5	102	97.5	93	98	94	101	105.5	111
d	114.5	101	97	100.5	101	91	93	99	94	99.5	94.25	105.5	119

Measures expressed in cm



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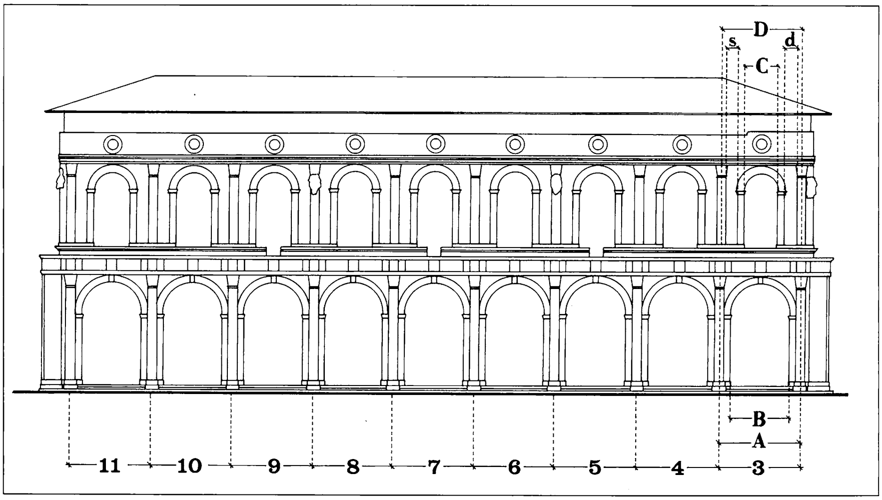

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Fig. 4 Side and front elevations of the Palazzo del Podestà (to be read with Table 1)

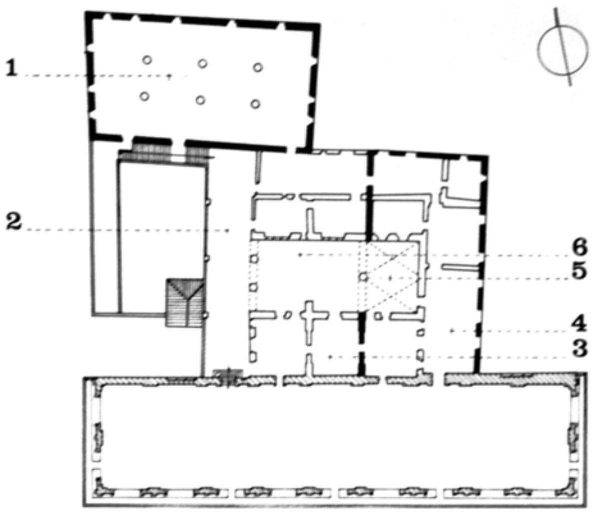

Fig. 5 Upper story plan of the Palazzo del Podestà, with building complex to the rear

This solution of adjusting the width of the bays is economical and logical, as it allows for corrections to be made through the manipulation of the "empty spaces", while leaving the masonry elements among them as consistently equal as possible. The strategy also serves a more subtle visual purpose, particularly on the east side, where the difference in width between the two lateral arches is most perceptible. By concentrating the variations in the arches, rather than in the piers, the narrow bay (2) at the head of the portico benefits from the optical effect of the voids surrounding it. The problem here is reminiscent of one of the several passages on optical corrections that Vitruvius describes in regard to the Ionic temple. In Book 3 of the *De Architectura*, Vitruvius states that a corner column appears thinner to the eyes, as if it were consumed by the air all around (Book 3, Chapter 8).[17] It can therefore be built bigger in order to correct the negative effect of the space around it, thereby making it look like all the others. The architect of the Podestà may have been inspired by this idea, but in a roundabout way, for he has used it to amplify the perceived width of a void rather than a solid. By using the empty spaces of the bays as an element of composition, the incompatibility of the two shorter sides is more readily concealed.[18]

Composition and Planning

The composition of the principal façade took a more straightforward path. The front elevation was established using the bay as the basic module, the width obtained by dividing the entire façade into nine intervals. That module measures 18 Bolognese feet—a whole number that is also easily divisible by 2 and 3. This module provided

Fig. 6 Rear facade of the Palazzo del Podestà

in turn whole-number dimensions for the long side of the pedestal at the base of the half-columns, which measure 3 ft, and the diameter of the base of the half-column, which is reduced to 2 ft (Fig. 7). In other words, the half-column is proportioned according to the measurement of the bay, with its diameter being a whole number so to facilitate the process of construction. The result is a ratio of exactly 1:9. At the same time, the height of the column works out to be 10 times its diameter. This ratio is rather slender for the Corinthian order, but is understandable in view of the unchangeable height of the ground floor.[19] The rest of the measurements are not multiples of the Bolognese metric system, but are calibrated according to the proportions established by the half-columns, giving the impression, in this case, that the secondary dimensions have been determined by geometrical constructions rather than arithmetical calculations.

The depth of the façade pillars, on the other hand, was not determined by the same proportional logic. That measurement was based on the depth of the angle

Fig. 7 Palazzo del Podestà, column base

piers, which was derived, in turn, by the length of the pre-existing medieval wall sections. There also appear to have been structural considerations at work here. Although lightened by great arched windows, the walls of the great hall on the upper story are further weighed down by the massive roof. As was known empirically in Gothic practice, the outward thrust of the roof truss required an increase in the depth of the pillar to counteract it. As a result, the pillars are deeper than is structurally necessary. Ultimately, the formal and structural logic of the building is based on the development of measurements in two different directions (along with two different rationales). On the surface of the façade, the architectural elements are determined according to "formal" issues of rhythm and proportion, while in the depth of the façade they are determined by the dimensions of the pre-existing structure and by structural considerations, with the pillars understood as having an important weight-bearing function.

The second level of the façade follows the same logic of the ground story (Fig. 8). The ratio between base and height of the pilaster is 1:7.5, while the width and height of the bays are equal, creating a square. This ratio is replicated in the widows, where the height of the small pilasters is equal to the total width of the window, a relationship further emphasized by the squared moldings of the small pilasters. Furthermore, the wall space between the larger and smaller pilasters is a quarter of the height of the window pilasters. Given the lack of obstacles posed by a pre-existing structure, the simple proportional relationships in the upper level stand out. Indeed, the prevalence here of the ratios 1:1 and 1:4 suggests some familiarity with Alberti's theory and practice.[20] It is also evident that some of the bays on this level are laid out carelessly. Indeed, the imprecise placement of certain pilasters is readily apparent to the

Fig. 8 Palazzo del Podestà, upper story window

naked eye, but these dimensional blunders appear quite random. That is, they do not contradict the sense of geometry in the building, appearing instead to be the result of sloppy construction.

Despite these discrepancies, the upper story also reveals some surprising subtleties. These are found on the eastern side, where the size and spacing of the windows have been slightly shifted to counteract visually the irregular widths of the bays below. While the window over bay 1 is positioned symmetrically over its corresponding archway, the window over bay 2 has been made 16.5 cm narrower, to correlate it, presumably, with the narrower archway below. That window, moreover, has been distinctly slipped toward the center of the façade. Rather than equalizing the space on either side of the window, the architect pushed the irregularities to one side, so that at least one of the dimensions—the distance of the window to the corner pier—matched those on the right bay.

Given this analysis, it seems that Fioravanti was conscious of the fact that applying an ideal geometrical system to a project, especially in the form of a grid, was not enough to reach acceptable formal results. In order to overcome the limitations imposed by the site, he considered the modular grid as a system not of geometric points but rather of clusters or bounded areas, within which vertical elements could be flexibly arranged. This operation was undertaken with a view to regularizing the proportional and rhythmical effects of the façade composition. Indeed, he appears to have often positioned irregularities in those areas of the elevation where they could be most easily hidden. That this was sometimes done through optical corrections suggests that Fioravanti worked with precise plans and elevations in order to articulate the relationships between elements, in particular the axes of the bays. Such a practice would also fit with Alberti's prescriptions.[21]

Construction

By keeping the dimensions of the masonry elements as consistent as possible, the builders obtained a second important advantage, namely the reduction of costs. The building records held in the Bologna State Archive reveal some interesting facts regarding this process.[22] In particular, a payment made to the stonemason Antonio Frangipani on 19 March 1492 for the masonry of the western side tells us not only the date of completion of the body of the building, but also lists the pieces paid for, moving from the lowest to the highest. From the prices in the document, we can see that individual elements such as pedestals, capitals, brackets, and *roxuni* (the rose motifs on the rusticated bosses), but also rounded forms such as the two great arches of the portico and the circular windows of the attic story, were all priced at consistent rates (Fig. 9). The Corinthian capitals of the ground story, for example, were much more expensive (16 *lire*) than the flat pilaster capitals on the upper level (6 *lire*) (Fig. 10). By the same token, varying quantities of different elements that required roughly the same amount of work—such as the rose motifs of the piers, the half-columns, and the architraves and cornice moldings of the large order—all cost the same: 8 *scudi* and 6 *denari*.

One curious feature of the price list suggests that the masons did not know how to calculate the length of curves. The sums paid for the masonry of the first floor arches are about 25 % more expensive than those paid for their corresponding second story cornices, which have identical moldings and are set in bays of the same width. We can surmise therefore that the 25 % increase is therefore based solely on the workmanship of non-rectilinear elements. This surcharge, however, is inadequate. The circumference, for example, of the ground-floor arch in bay 2, measured on the intrados, is 8.07 m (21.6 Bolognese feet). That is 36 % longer than the width of the bay. Although masons' rules-of-thumb are by nature rough and approximate, this discrepancy does seem surprisingly large.

Fig. 9 Palazzo del Podestà, side facade

The masons may very well have charged a different amount for each arch, according to its characteristic size and form. As we have seen, almost all of the arches vary in size according to the different widths of the bays, particularly those on the short sides, which are considerably larger than those of the principal façade. But that variation would not have affected the consistent and standardized means of pricing per piece of masonry. That mechanism points to the use of exact and repeated dimensions—one might say serial or even standard—to optimize the production and cost of individual elements. By standardizing the size of the parts while manipulating the voids, not only are the irregularities of the façade better hidden, the masonry elements themselves can be produced offsite, thereby reducing costs and simplifying the construction process. The construction of the Palazzo del Podestà shows how a clear and regular geometry not only facilitates the composition of a building but also serves as a cost-efficient parameter of its construction, providing a powerful tool for patron, architect, and builders alike.

Fig. 10 Palazzo del Podestà, capitals from the half-columns of the ground story, to be compared with those from the pilasters of the upper story (Fig. 8)

Notes

1. Carpo (2003). For a recent account of the role of quantification and measurement in early Renaissance architecture, see Cohen (2013).
2. The notion of precision appears at the beginning of Leon Battista Alberti's *De Re Aedificatoria,* in relation to the role of the architectural drawings. See Alberti (1988,7). The bibliography on the issue of proportion in Renaissance Architecture has become vast and unmanageable. See Wittkower (1988). For a recent overview on the topic see Curti (2006, 65–138).
3. The use of the geometrical grid in order to reproduce the human body in painting was already known during the Gothic era. Villard de Honnecourt, for example, represents a woman's head proportioned in this way. See Barnes (2009, fol. 38). Lorenzo Ghiberti describes a human figure using the same method in the

first *folio* of his third commentary. See Ghiberti (1998). This tool was also widely diffused among architects of that time as a tool for composition and design. Antonio Averlino (Filarete) begins the plan of Sforzinda's Cathedral from a square grid of 15 modules on each side, though its function is only for proportioning and dimensioning, less for composing. Another grid appears in the book for the design of the *Casa Regia*. See Averlino [Filarete] (1972, vol. 1, 182–183, 207–208; vol. 2, Fig. 24). For another example, see Martini (1967, Fig. 236). A famous architectural drawing that clearly shows the grid as a tool of design is Bramante's plan of Saint Peter's, Uffizi 20. See Thoenes (2006) with bibliography on the drawing. Further analysis of fifteenth- and sixteenth-century plans and drawings would likely turn up other examples.

4. For the history of Vitruvius' treatise, see Pagliara (1986). For the history of Alberti's treatise, see Orlandi (1994). Also see Burns (1998, 120).
5. Libri Mandatorum, reg. 17, fol. 30r, Archivio di Stato di Bologna. Published in Sighinolfi (1909, 57–58, 147).
6. For the attribution, see Benelli (2001, 47–68 and 2005a, 100–103) with complete bibliography on Aristotele Fioravanti. For a brief but detailed biography of Fioravanti, see Ghisetti Giavarina (1997).
7. Müntz (1878, vol. 1, 83, 108). Bertolotti (1886, 2).
8. The transport was accomplished not by dismantling the tower but by splitting it from its foundations and carrying it vertically on a wooden cart over a track at the bottom of a trench. See Pattaro (1976).
9. For the phases of construction, see Benelli (2005a, 73–87). For Fioravanti in Russia, the bibliography is quite extensive, but see the complete list in Ghisetti Giavarina (1997).
10. Earlier attempts to reconstruct the proportional basis of the façade have been suggested by De Angelis and Nannelli (1976) and Licciardello (1991). Neither of these reconstructions, however, considers the irregularity of the site.
11. The survey, made with traditional methods, was organized and executed by the author with the help of Anna Maria Moro, Lucia Bacchiani, and Vittorio Pizzigoni.
12. This road served to link the Via Emilia—connecting Rimini with Milan across the Po Valley—with the new *Platea Comunis,* a rectangular piazza created along with the first communal palace from 1200 to 1203. Within the city wall, the Via Emilia was the *decumanus maior* of Roman Bologna, to become one of the busiest streets of the city during the Medieval period and beyond.
13. Part of the medieval structure was revealed during heavy restorations by Alfonso Rubbiani beginning in 1905. For a brief synthesis of the restoration, see Mazzei (1979).
14. One Bolognese foot is 0.380098 cm. See Martini (1883, vol. 1, 92). A Bolognese brick during the Renaissance was 28.50 cm long, 12.66 wide, and 6.33 high, or 9 by 4 by 2 Bolognese inches. See Benelli (2005b). Reprinted in Ricci (2007, 75–94).
15. This sort of "elastic system" is actually common among medieval Bolognese porticoes, which were normally adjusted according the preexisting façade to which they were attached. For a similar topic, see Hubert (2001, 33–34).

16. This elevated terrace was built from 1438 to connect the medieval palaces of the compound, the so-called Palazzo di Re Enzo and the palace of the Capitano del Popolo, with the Palazzo del Podestà, also creating a uniformed loggia façade facing west. The original *iter in voltis* was destroyed in 1572 for the construction of a building to house the Auditori della Sacra Rota, employed in the local Vatican Court. It was rebuilt in the same shape by Alfonso Rubbiani in the beginning of the twentieth century. On this feature, see Benelli (2005a, 74, 108).
17. "Etiamque angulares columnae crassiores faciendae sunt ex suo diametro quinquagesima parte, quod eae ab aere circumciduntur et graciliores videntur esse aspicientibus." Vitruvius (1997, vol. 2, 247). The same optical refinement was underlined by Alberti (1988, 215–216). Vitruvius was known in medieval Bologna. A manuscript copy of the text belonged to the university lecturer and canon Giovanni Calderini as early as the fourteenth century. See Ibanez (1998, 62). Further copies of the treatise are accounted between 1426 and 1455. They belonged to Carlo Ghisilieri and Cardinal Bessarion, the latter appointed *Legato apostolico* in Bologna from 1450 to 1455. See Hubert (2001, 35).
18. The dimensional consistency of the pillars also reflects an appreciation of ancient practice, as in, for example, the Colosseum, the Tabularium, and in general all Roman theaters. As Christoph Thoenes has pointed out, such consistency is rare in Renaissance loggias. The Bolognese case is best seen therefore not a superficial imitation of Roman classical architecture, but rather as an attempt to recreate its "structural substance". Thoenes (1998, 59–65).
19. Both Alberti (Book VII, Chapter 6) and Filarete (Book VIII) recommend the height of a Corinthian column to be eight times its diameter. See Alberti (1988, 201) and Averlino [Filarete] (1972, vol. 1, 218). Vitruvius' description of the Corinthian order is more complex (Book III, chapt. 5, 1–9; Book IV, chapt. 1, 11). Though generally broader, it includes in some cases proportions of 1:10. See Vitruvius (1997, vol. 1, 255–259, 369–375). Alberti faced same problem in designing the façade of Santa Maria Novella in Florence, where he was also forced to stretch his columns beyond their theoretically ideal proportions. See Benelli (2005a, 93).
20. Fioravanti may have known Alberti from 1451 to 1452, when they are both documented at the Vatican working under Nicholas V. It was precisely at this time, in fact, between December 1451 and January 1452 that Alberti presented his manuscript of the *De Re Aedificatoria* to the Pope. See Burns (1998, 120). On Alberti's work for Nicholas V, see Tafuri (1992, 33–88) and Frommel (2005). Fioravanti may also have been familiar with Alberti's project for the Tempio Malatestiano in Rimini, which also involved "wrapping" a classical envelope around a pre-existing medieval building. For a chronology of the Tempio, see Hope (1992).
21. Examples of optical refinements in Alberti's buildings are found, for example, in the portal of Santa Maria Novella in Florence and in the façade of Sant'Andrea in Mantua. See Bulgarelli (2007) and Curti (2007).
22. "Massarolo dei Lavori, Spese relative al Palazzo del Podestà," 13r–15r, Archivio di Stato di Bologna. Partially published in Valeri (1895, 251). Also see Valeri (1896, 78) and Zucchini (1912, 14).

Photographic Credits

Author: Fig. 1, 3–10
Biblioteca Archiginnasio, Bologna: Fig. 2

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