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**Abstract.** On the basis of a new survey, Angela Pintore analyzes the micro-architecture of the Rucellai Sepulchre in Florence, because the sepulchre is the only object designed *ex novo* by Leon Battista Alberti. Attention is also given to the relationship established between the sepulchre and the chapel that houses it, and to the modifications made to the chapel by Alberti himself. Alberti studied carefully the combinations between the number of the elements of the front elevation and that of lateral elevation and of the apse so that the relationship between them would recall the harmonic musical ratios that he set forth in *De re aedificatoria*, in which he outlines the correspondence between architectural proportions and harmonic musical ratios that will become the element that characterizes Renaissance architectural theory, inaugurating a tradition that will begin to see a decline only in the eighteenth century. In spite of the myriad difficulties of establishing if these speculations had indeed any concrete effect on architecture, it is clear that Alberti's theory is not the result of individual reflection, based solely on the classical sources that Alberti himself explicitly cites in his treatise, but rather is the summit of an age-old tradition of thought that, during the whole arc of the Middle Ages, had deepened the study of the symbolic and expressive value of harmonic ratios.



## Musical Symbolism in the Works of Leon Battista Alberti: from *De re aedificatoria* to the Rucellai Sepulchre

**Angela Pintore**  
Via Pisana 22  
50143 Florence ITALY

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### INTRODUCTION

The Rucellai Sepulchre has been the object of numerous studies,[1] which are often accompanied by graphic representations (**Fig. 1**). However, the lack of recent in-depth studies regarding the proportional matrix used by Alberti in designing this small architecture made a new measuring campaign necessary. The point of departure for this investigation was the surveys executed by Gastone Petrini [1981] on the occasion of the restoration work of the Chapel in the 1970s, of which some of the original drawings at a scale of 1:20 are available at the Sovrintendenza ai Beni Culturali of Florence. However, a series of motives made it necessary to undertake new measurements:

- The plates of the Sovrintendenza were part of a set of drawings made in the interim before a complete documentation was undertaken, so that the survey is incomplete; it is impossible to find, for example, the side elevations;
- The plates, though drawn at scale, do not provide the dimensions; in the absence of certain measurements, the small scale of the funerary sepulchre (the central nucleus measures 2.26 x 3.28 x 2.23 m) makes it difficult to take off of the plans the exact dimensions of the marble facing;
- The survey was executed as part of the work to consolidate the vaulting, so that the Sepulchre is an element of secondary, decorative, importance rather than the object of an attentive measured investigation.

In spite of these limitations, the survey of the Sovrintendenza was indispensable to

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the reproduction of the vault of the Chapel and of the small ciborium on top of the Sepulchre, elements which it was not possible for me to survey on my own. The survey that I undertook was accomplished with the aim of interpreting the proportional relationships that govern the construction. The measuring campaign was undertaken with the use of traditional methods, that is, with a measuring tape and meter rule, without the use of electronic devices.

As to theory, as a means of validating the results and the hypotheses of the present study, I compared them with those published in the early 1960s by Bruschi [1961] and Dezzi Bardeschi [1963, 1966] which, although almost 40 years old, remain the only in-depth analyses of the dimensions of this work of Alberti.

The present study, as well as previous ones, has shown that the search for the proportional grid shows itself to be insidious, and that the co-existence of explicit margins of error must be accepted. These are perhaps justifiable if we consider the complex genesis of any manmade object and the inevitable dialectic between the intentions of the designer, the interpretation of those intentions by the direction of the work, and the actual intervention of the labourers. The use of the computer in the present day, with its graphic precision that shows no mercy, makes all too clear discrepancies that drawings carried out by hand tend to hide; this is even more the case when, as happens in numerous cases, the proportional research is carried out on small compositional schemes.[2]

Thus it is necessary to undertake a previous study, almost philological, of the motivations, aesthetics, and symbolism that could have lead the designer to prefer predetermined geometric constructions, as well as the necessity to govern the whole of the project through the use of proportional matrixes, avoiding the extrapolation of single elements or particular views, however significant those might be, as they frequently lead to discordant interpretations, without however adding to the comprehension of the integral design precepts that lie at the base of ancient architecture.

#### **THE RUCELLAI SEPULCHRE: PROPORTIONS AND MUSICAL SYMBOLISM**

Alberti's design takes as a point of departure the small hall annexed to the Vallombrosan convent of S. Pancrazio in Florence, to which the Rucellai family had been tied for generations.[3] The work commenced probably at the beginning of 1459, according to a design by Alberti, and may have been carried out by Giovanni di Bettino, the very capable master of intarsia who executed the façade of S. Maria Novella, also designed by Alberti for the Rucellai family. The chapel was originally separated from the church of S. Pancras by a wall, which Alberti daringly demolished and substituted with an architrave supported by two columns and two pilasters. Further, the perimeter walls were made about a meter higher, three windows were opened onto Via della Spada, and the interior decoration was completely revamped, from the pavement with its geometric inlay to the execution of a light barrel vault. Unfortunately, the original appearance of the whole underwent a significant intervention in 1808, during the reign of Napoleon, when the church was deconsecrated after the suppression of the Vallombrosan community, and the wall that had been demolished by Alberti was reconstructed, and his trabeation and the columns now decorate the façade of the church.[4]

The actual sepulchre is located in the interior of the hall, its design intended to recall the typology and proportions of the Holy Sepulchre of Jerusalem.<sup>[5]</sup> The present study aims to analyze this micro-architecture, because the sepulchre is the only object designed *ex novo* by Alberti, though attention must be given to the relationship established between the sepulchre and the chapel that houses it, and above all, to the modifications made to the chapel by Alberti himself.

The Sepulchre, rectangular in plan with a semi-circular apse in the rear, is entirely clad with modular elements of marble, pilasters alternating with square panels inlaid with heraldic circular and geometric motifs, repeated with a margin of error that is less than 2mm. Once the measurements were taken, it was possible to mediate that error with simple mathematical algorithms in order to obtain a model of the Sepulchre that was composed of identical elements, while the dimensions as a whole were maintained as they were. The basement is made up of a low moulded base, the crown of two series of mouldings, on which is placed a band bearing an inscription in Roman characters, topped by a crown of lilies. On top is a wooden, domed, ciborium, which may be a relatively recent copy of an original that is now lost [Dezzi Bardeschi 1963: 149]. Both on the ciborium and in front of each lily are metallic points to hold the wax candles that would decorate the Sepulchre on holy days. The interior is made of a rectangular hall with barrel vaults, frescoed with polychrome cornices and scenes of the Passion, attributed to Alessio Baldovinetti (1425-99), while the ceiling is decorated with golden stars arranged geometrically against a field of blue. On the side of the entrance a marble sarcophagus occupies almost the entire length of the small interior.

Alberti studied carefully the combinations between the number of the elements of the front elevation and that of lateral elevation and of the apse so that the relationship between them would recall the harmonic musical ratios that he set forth in *De re aedificatoria*. Particularly admirable is the command with which he articulates physical resemblances and those that are of more or less close relationships conceptually: on the apse there are no true pilasters, but only vertical stripes in the decoration; further, on this side not even the inlaid panels, with their curvature and the slightly elongated dimensions, are exactly similar to those on the front and lateral elevations. The opening for the door, topped by a square inscription panel rather than a circular inlay as are the other thirty that decorate this small edifice, introduces an ulterior diversification, rendering the calculation of the partitioning anything but banal and multiplying the possible interpretations.

The table below recaps the number of the architectural elements present on each side, noting by the use of quotation marks those that have undergone some kind of mutation:

|                   | front            | side | rear    |
|-------------------|------------------|------|---------|
| pilasters         | 3                | 4    | "2" + 2 |
| intercolumnations | 2                | 3    | "3"     |
| squares           | "1" +<br>"2" + 3 | 9    | "9"     |

|        |                            |                            |                            |
|--------|----------------------------|----------------------------|----------------------------|
| lilies | $5 + 2 \times \frac{1}{2}$ | $7 + 2 \times \frac{1}{2}$ | $7 + 2 \times \frac{1}{2}$ |
|--------|----------------------------|----------------------------|----------------------------|

It is possible to distinguish harmonic relationships both by taking into consideration the number of the similar elements present on the various elevations, as well as by comparing the numbers of the diverse elements that characterize each individual elevation. The influence of the harmonic musical relationships can also be distinguished in the dimensions chosen.

Taking as a point of departure the front elevation (**Fig. 2**), it is possible to identify the width of the pilasters, 22 cm, as the module of measurement of the architecture. This is very close to the Roman palm (22.35 cm), as evidenced by Dezzi Bardeschi [1963: 151; 1966: 21]. Seen in this light, the fundamental nucleus of the front elevation, stripped of its pilasters, base, and cornices, is an approximate square with sides equal to 222.8 cm long and 223.4 high, approximately equal to 10 pilasters, and even more closely equal to 10 Roman palms. Further, 22 cm is the height of each of the three cornices above the capitals, two of which are composed of mouldings, the middle of which bears the inscription in Roman characters. The same module repeated two and a half times delimits the height, including the base, of the crown of lilies (45.4 cm + 9.6 cm = 55), which the height of the base (11.7 cm) is just about one-half module. The maximum projection of the crown, calculated without taking into account the protrusion of the pilaster, corresponds yet again to one module per side cm 267.1 - 222.8 = 44.3 cm; 44.3 : 2 = 22.15 cm).

The mass of the rear elevation can be enclosed in a rectangle whose base is 267.1 long and 356.2 high, equal to about 12 x 16 modules (12 x 22 = 264, 16 x 22 = 352). The sides of this rectangle therefore express the sesquialtera (one and a third), or 4:3. In this case as well it is possible to reduce the margin or error by substituting for the 22 cm of the width of the pilaster the 22.34 Roman palm (22.34 x 12 = 268.1 cm; 22.34 x 16 = 357.44); it is possible to reduce the margin of error to practically zero if the modular approach is abandoned and the musical ratio is applied to the length of the base ((267.1:3)x4=356.1).

In 1932, Dezzi Bardeschi identified the grid of the golden rectangle in the dimensions of the entrance to the sepulchre [1963: 158 and fig. 16].<sup>[6]</sup> Even though this is acceptable from a metric point of view (including in the measurements the cornice, one obtains 80 cm x 1.618 = 129.4 cm, while the value I obtained in my survey was measured was 132.4), the application of the golden ratio in Alberti's architecture appears to force the argument, considering, as Dezzi Bardeschi himself pointed out, that not a trace of the golden ratio is found either in *De re aedificatoria* or other of Alberti's writings. Further, it is important to emphasize that, with the same margin of error, it would be possible to reduce the entrance to a simple construction of a double square (considering only the opening, we have 63.4 cm x 2 = 126.8 cm, in contrast to the 124 measured during the survey); Alberti recommended the use of the double square in the context of harmonic areas. Further, conceptually the opening of the door substitutes two of the inlaid squares, which constitutes an additional reason to favour the second hypothesis, in spite of the larger margin of error, which when expressed in terms of percentage is 2.19% for the construction proposed by Dezzi Bardeschi and 2.26% for my hypothesis.<sup>[7]</sup>

The relationship between the sepulchre with the chapel that contains it is also

exquisitely harmonic. The cross that tops the small dome marks almost exactly the centre of the chapel and, approximately marks as well the third both in height and in width. The rectangle formed by taking the outer lines of the pavement, the top of the vault and the centrelines of the perimeter walls has its sides in the sesquialtera ratio (one and a half), or 3:2.

Dezzi Bardeschi's hypothesis, which reduces the ratio between width and height of the hall to the golden rectangle [1963: 158 and fig. 16], appears once again to be problematic, not so much because it is based on a metric approximation, which is in any case acceptable given the admitted irregularities of the dimensions (the extreme irregularity of the object, which Dezzi Bardeschi himself emphasizes, together with the use of pilasters and arches that punctuate the barrel vault, give rise to measurements that lend themselves to multiple interpretations), but rather because there is no valid basis in theory to justify the use of the golden rectangle.

The research into and the compositional schemes for the side elevations (**Fig. 3**) is conditioned by margins of error that are decidedly greater than those for the front elevation. This may be because Alberti wished to compose the two elevations with elements that were dimensionally identical and the number of which was modulated, as has already been emphasised, by musical relationships. The search for a macroscopic harmony of the number of the parts leads to an inevitable compromise regarding the harmonic meter that is the most difficult to appreciate, which, however, even when lacking in quantitative precision, makes itself felt qualitatively. The analysis of the present study underlines how the approximation of harmonic relationships does not come about coincidentally but is generated by the addition or subtraction of modules or fractions of modules. Thus in this case as before, in the identification of the compositional schemes the width of the pilaster is of key importance. However, the imperfect coincidence of the width of the pilaster with the Roman palm indicates a kind of metric polisemia in the identification of the schemes used, which can be interpreted with various approximations, both in relationship to the palm as well as to the pilaster as a self-referential constructive module.

If we consider the nucleus of the side elevation, stripped of pilasters, base, cornices and apse, as a rectangle whose height is equal to 10 pilasters (223.4 cm), and whose width is approximately equal to 15 pilasters (324.8 cm by survey, where  $22 \times 15 = 330$  by calculation [8]), then we ascertain the approximate harmonic ratio of sesquialtera (one and a half), or 3:2. If we substitute the length of the pilaster with the Roman palm, then rectangle identified is exactly 10 palms high and 14.5 palms wide ( $22.34 \times 14.5 = 323.93$  cm). The margin of error when using the harmonic ratio is thus not coincidental, but is equal to a defect of one-half module. Taking into account the projection of the apse, which measures 88 cm or 4 pilaster widths, then we obtain for this scheme a length of some 19 pilaster widths, which constitutes, with respect to the height of 10 pilaster widths, a ratio of a double square minus one module.

By inscribing the elevation in a rectangle in the same way that was done for the front elevation, it is possible to verify a relationship that is very close to a sesquitertia (one and a third), or 4:3. The margin of error that is involved in this relationship is rather significant, but neither is this casual. The width of the rectangle is 458.5 cm, equal to 20.5 Roman palms ( $22.34 \times 20.5 = 457.97$  cm), while the height is 356.2 cm, or 16 palms ( $22.34 \times 16 = 357.44$  cm). The error therefore corresponds, as evidenced by the graphic verification, to about one-half module in width and a module in height. Subtracting from the total length, 458.5 cm, the height of the basement (11.7 cm), we

obtain a length of 446.8, which divided by 4 and then multiplied by 3 gives 335.1 cm, which is 21.1 cm less than the height of the elevation, which is 356.2 cm. The geometric construction from which this is derived, with the width of the base as the length of reference, has a certain fascination.

According to the same logical process, it is possible to hypothesise for this elevation a sesquitercia ratio based on the module that derives from the width of the pilaster. The width is very close to 21 modules ( $22 \times 21 = 462$  cm), while the height is equal to some 16 modules ( $22 \times 16 = 352$ ). In this case, to each of the terms of the harmonic ratio has been added a length equal to one module.

The mass of the sepulchre is equal to about one-third of the chapel that contains it, even if the centre of the wooden dome of the sepulchre corresponds only approximately to the centre of the centre of the architecture of the chapel. Ideally, the centre of the dome would match the small hole in the centre of the vault, but it is in fact slightly forward of that.

The imprint of the geometric use of the Pythagorean musical ratios appears as well in the decoration of the chapel: the windows are framed in rectangles that from pilaster to pilaster, and from base to base, are in the sesquialtera ratio, one and a half, or 3:2 (the height is equal to 552.3 cm, while the width varies from 370.2 in the rectangle on the left, 363.2 in the central rectangle, and 364.9 cm in the rectangle on the right ( $(552.3 : 3) \times 4 = 368.2$ ). The overall chapel has a width-height ratio of 32:27, which corresponds to a Pythagorean ratio of the minor sixth (at the central section the width is about 1041 cm (compare to an ideal calculated width of 1039.5 cm), while the height is 1232 cm).

The theory set forth in 1961 by Bruschi [Bruschi 1961: 124 and fig. 10], later taken up and expanded on by Dezzi Bardeschi [1963: 157-159 and fig. 17; 1966: 21], according to which the width of the trabeation is the modular element of the Rucellai Chapel, doesn't seem to bear up to scrutiny. The construction is acceptable if applied at the height of the perimeter walls that, from the pavement to the trabeation, corresponds to about four modules (the height of the trabeation is in fact equal to 148 cm, while the wall is 586 cm high, with a deviation with respect to the ideal construction of 6 cm). The application of the of the module itself to the height of the vault, which should correspond to  $148 \times 2 = 296$  cm, is instead equal to 307 cm. Further, according to Dezzi Bardeschi, half of the width of the trabeation should correspond to the width of the base of the pilaster, that is, they should be 74 cm long, while the survey revealed that these elements were not even equal, and had widths of 76 and 79.6 cm. The hypothesis derived by Dezzi Bardeschi holds that the rectangles comprised between the pilaster and the trabeation are modulated by a ratio of 8:5, which would be an approximation for the golden ratio: the height should be equal, as mentioned above, to  $74 \text{ cm} \times 8 = 592$ , while the width should equal  $74 \times 5 = 370$  cm. Neither Bruschi nor Dezzi Bardeschi make it clear that the three rectangles investigated are not equal, and Dezzi Bardeschi does not find any contradiction in accepting, along with his own theory of the 8:5, that of Bruschi that identifies the golden ration as the grid of the rectangle on the right, which measures  $586 \times 364.9$  cm, and thus has a width that conforms to the 366.25 of the hypothetical constructions.

In plan (**Fig. 4**), the total volume of the Sepulchre can be inscribed in a rectangle of musical ratios that correspond to a double sesquialtera with the smaller side equal to

approximately 11 times the width of the pilaster (for the smaller side,  $22 \times 11 = 242$  is in fact very close the 241.8 cm in my survey; for the larger side 241.8 divided by 3, then multiplied by 4 equals 429.8, very close to the 431.8 of my survey).

Further, because the front is based on a square, the rectangle of the lateral inlaid walls, stripped of their cornices and pilaster is equal to the rectangle that delimits the Sepulchre in plan (223.4 cm x 324.8 cm for the lateral walls, against the 22.8 cm x 324.8 cm for the plan).

It is possible to identify a further musical ratio, based on the progression of lilies, the volume of which corresponds in plan to that of the base. The lilies are found in the ratio of 6:8, equal to 3:4; however, that same ratio can be found in the measurements of the sides of the sepulchre in as much as the width of the decoration is masterfully varied in the transition from the long side to the short, as can be seen by the grid that connects the peaks of the lilies themselves.

Measuring the perimeter of the side with the apse it is possible to verify the equality of its length and that of the long side of the Sepulchre:  $23.5 \text{ cm} + 88 \times 3.14 + 23.5 = 323.32$ , a dimension that is very close to the 324.8 of the long side. Paradoxically, the small quadrangular architecture has three equal sides, each 14.5 Roman feet long, and one that is shorter, at 10 Roman feet, the measure of the Roman canna.

The chapel turns out to have in plan a very simple development based on what Alberti himself described as a "double area". Dezzi Bardeschi had made this correspondence evident [1966: 20], which was in any case very prominent in the Middle Ages (it should not be forgotten that Alberti was working in an existing space, modifying it only in part), emphasising, however, the extreme irregularity of the pre-existing conditions that determines very different lengths for corresponding sides. With regards to this I was able to identify that if one considers a rectangle that takes as its reference not the walls, but rather the bases of the pilasters, one obtains a figure that is rather regular, the long side of which measures exactly twice the short side, according to the musical ratio of the octave. The construction not only justifies the irregularity of the projection of the base, but demonstrates as well the wish of the designer to "regularise" as much as possible the frame of his own design intervention. In this light, the hypothesis held by Bruschi, according to which "the plan of each bay (from wall to wall) turns out to have a ration of 2 to 3," can be partly acceptable, since by dividing into three bays the total rectangular space having one side that is the double of the other, the result is rectangular spaces that are in the ratio of 2:3. However, Dezzi Bardeschi had already pointed out had Bruschi's second hypothesis, according to which "the free space of every bay is a golden rectangle," could not be confirmed by the dimensions.

It is more difficult to find the proportional grid that governs the inlays of the pavement. The various attempts turned out to be misleading, and only some of the rectangles appeared to be based on precise geometrical constructions.

The interior of the Sepulchre shows that much less care was given to the interior than to the exterior: the walls are deformed by projections and bumps and as a consequence the proportional grid can be defined with much less precision. The hypothesis of Dezzi Bardeschi that traces the transversal section of the Sepulchre (**Fig. 5**) back to a golden rectangle that comprises the thickness of the vault is

confuted by the survey, in that the height, equal to 301.1 cm, and the width, 175.2 cm, do not correspond to the golden ratio. The error can perhaps be ascribed to a overestimation of the thickness of the vault, which, in the drawings, although no dimension is given, comprised the base of the lilies as well.

It is possible, however, to find a particular proportional grid similar to that already identified for the side elevation, based on approximations of harmonic ratios. If one considers as a reference the circumference that generates the shallow barrel vault of the small space (175.3 cm), one obtains a module of 187.6 cm, only 12.3 cm from being equal to the width of the space. This module, multiplied by 1.5 according to the sesquialtera ratio, 3:2, generates a length of 281.4 cm, only 10 cm from being equal to the height of the space (271.4 cm), thus very similar to the previous ratios. It is particularly striking that both of the errors are close to 11 cm, or one-half the width of the pilaster and thus can be traced to a fraction of the module according to the same process of approximation that we have identified as the margin of error of the proportional grid of the side elevation. These clues lead one to think of the systematic use of the musical ratios from whose terms are subtracted pre-determined modules: mathematically the ratio loses its validity, but it is possible to graphically retrace its genesis.

It is further evident that Alberti's repeated resort to the sesquitertia ratio, which is present in both the elevations as well as in the plan, where it is found in the form of a double sesquitertia. This fact is in accordance with the instructions given in *De re aedificatoria*, where the designer is advised, in the determination of the three dimensions of a building, to use proportions that are all derived from the same sequence of harmonic relationships, and not to use the various sequences in a haphazard manner [Alberti 1999: Bk. IX, ch. 6, 307].

#### MUSICAL SYMBOLISM FROM PYTHAGORAS TO *DE RE AEDIFICATORIA*

*The very same numbers that cause sounds to have concinnitas, pleasing to the ears, can also fill the eyes and mind with wondrous delight* [Alberti 1999, Bk. IV, ch. 5: 305]. With these words Leon Battista Alberti outlines in his *De re aedificatoria* the correspondence between architectural proportions and harmonic musical ratios that will become the element that characterizes Renaissance architectural theory, inaugurating a tradition that will begin to see a decline only in the eighteenth century. [9]

To underline the incontrovertibility of this simple axiom, Alberti cited the "noted sentence of Pythagoras," according to which "it is absolutely certain that Nature is wholly consistent" [Alberti 1999, Bk. IV, ch. 5: 305], a precept taken from the most ancient Greek philosophy that recurs often in the treatise, so that it becomes a kind of connecting thread within it: even when not explicit, Alberti in fact uses it, drawing the precepts for making architecture from fields such as biology and mathematics, physiology and music, astronomy and geometry.

At times the reasoning with which the author deduces, starting from these disciplines, the rules of building is a kind of cause-and-effect: good sense, the constructive practices consolidated through the centuries, the knowledge of materials and physical laws, even if at times imprecise and full of gaps, suggest some behaviours and precautions according to a logical process that, even in the light of our actual post-Galilean vision, it is not problematic to define as scientific.

More often the relationship is of a symbolic kind: numbers and proportions are preferred to others in that they are recognized as "recurrent" in situations or events in nature, and because they gifted notable mathematical or geometric characteristics, rendering them, to use Alberti's own definition, depositories of particular "properties" [Alberti 1999, Bk. IV, ch. 5: 304], to which the designer must refer in determining the form to be built. What is derived is an architecture that is strongly descriptive from a symbolic point of view, which, in its most successful examples, is the acme of the knowledge and world vision of the epoch that produced it.

In spite of the fact that the contemporary culture greatly admired these accomplishments, the interpretation of the symbolism that underlies them tends to underrate the importance of the design choices that generated them, interpreting the symbol exclusively as a linguistic sign. From this point of view, the square, the number 7, the golden rectangle, etc., referring to a meaning or a family of meanings, are nothing more than "words" in a discourse. The architecture that connects them can therefore be decoded as the "narrative" of a superior cosmic harmony. The error consists in the application of a contemporary vocabulary, borrowed from studies on the techniques of visual communication, to works of another epoch. The interpretation of the relationship between symbol, meaning, and real object in terms of pure semantic reference is nevertheless a concept that is alien to ancient and medieval cultures, and in great measure, to modern culture as well.

In occult thinking, symbol, meaning, and real object are blended. Symbol participates in the nature of the referent either because it contains a part of it, or because it reproduces the likenesses, or simply because it carries its name, thus consenting the magical action to become explicit in the symbolic object, provoking a mutation of the reality. This translations assumes an even greater weight if it refers to a mathematic-geometric symbolism, considered to be, within the context of the various cultures, capable of reproducing the primary origin that underlies the apparent chaos of the actual. Modelling one's own work according to the numbers and figures that preside over the harmony of the universe, the architect is forced to achieve a perfect consonance with it, guaranteeing that the object will have a beauty and solidity and inspiring the beholder to contemplate truth. The symbol is not a "word" in the architectural discourse but a guarantee of quality for the architecture that conforms to it, and as a consequence, the architecture does not "narrate" the original project of the universe, but rather becomes a part of it.

In the search for the proportions that best responded to these aims, the analysis of the harmonic musical ratios assumed a fundamental importance as early as the fourth century B.C., when Pythagoras, according to a legend that was diffuse in the middle ages and probably was not without historical foundation, discovered that at the base of two consonant sounds there are simple mathematical ratios between the size of the objects that produced them.[10] This law, which is universally valid, is expressed with greater evidence in sounds that are produced by two chords equal in material, thickness, and tension but of different lengths. In particular, the school of Pythagoras reduces all the possible accords to ratios between powers of numbers 2 and 3, setting musical harmony in relation to the tetraktys, the sequence of the first four whole numbers that, in Pythagoreanism, represent the revelation of divine order: beginning with an initial sound that corresponds to C, it is in fact possible to identify a concordant sound F, produced by a chord whose length is equal to  $\frac{2}{3}$  of that which produced the C, the resulting concordance C-F being defined as a fifth, because five

notes make up the interval. In its turn, a chord whose length is  $\frac{2}{3}$  of that which produced the F will produce a sound that is even more acute, that is, D of the next octave. Proceeding in this manner in ascending fifths, it is possible to define in twelve passages all of the tones and half-tones of the Pythagorean musical scale. The resultant sounds are obviously distributed over the arc of several octaves, seven to be precise, and the length of the corresponding chords must be divided by powers of 2 in order to bring all of the notes to within the octave of reference.[11]

Though the Pythagorean scale is probably the most ancient, it is not the only scale that was set out in the complex sphere of Greek musical theory. However, with its strong numeric symbolism, with the governing numbers 1, 2, 3 being reinterpreted by ways of three, it would become the basis of medieval musical theory, in spite of the difficulties of using it to express all possible consonances.[12]

The implications drawn by ancient philosophy from the discovery of the numerical value of consonances greatly extended beyond the realm of musical theory. Pythagoras himself interpreted them as irrefutable proof of the mathematical order of the universe. According to him, the musical harmonies governed the movements of the planets, which produced a sort of incessant cosmic melody. The musical theory of the spheres enjoyed an enormous fortune, and conditioned nearly all successive philosophies. Even as late as 1619, Kepler, in his *Harmonices Mundi Libri V*, not only expounds his famous laws demonstrating the elliptical geometry of the orbits of the planets, but he lingers over the definitions of the melodies generated by each planet, transcribing them on a pentagram and making them part of his treatment [Shea 1992, II: 177-178].

In the sixth century B.C., Plato, in *Timaeus*, describes the Demiurge in the act of giving form to the chaotic material according to a series of mathematical proportions that exactly replicate the genesis of the Pythagorean musical scale.[13] The only Platonic text known in the Middle Ages—in fragmentary form and through the writings of the Latin neo-Pythagoreans Calcidius and Macrobius—*Timaeus* was considered a summa of ancient wisdom, and had an enormous effect on Scholastic philosophy.[14] In spite of the value placed on the harmonic musical ratios, art for Plato—for all that it was a copy of reality and was based on ideas drawn from the realm of forms—was not a copy of a copy, and therefore assumed the value of a negative in the process of bringing men closer to knowledge. Only with neo-Platonism, around the third century A.D., would this relationship be reversed: art came to be interpreted as a representation of ideal forms and became the preferred path in the search for truth.

It was in this context that St. Augustine, in his *De Musica* (386 A.D.), posited that mathematical order and the universal significance of the numbers of which that order is made were fundamental to the beauty of musical poetry.[15] And it is in this context that the parallels that would be later drawn by Alberti between numeric musical harmony, rhythms perceived by the ear, and rhythms of three-dimensional objects that are perceived by the eye is made explicit:

*...dunque queste cose belle piacciono a cause del numero in cui, come abbiamo già mostrato, si ricerca l'ugualianza. D'altra parte tale numero non si trova soltanto nella bellezza pertinente all'udito e che si fonda sul movimento dei corpi, ma anche nelle stesse forme visibili, a proposito*

*delle quail si parla più comunemente di bellezza* (thus these beautiful things are pleasing because of the number in which, as we have shown, equality is sought. On the other hand, this number is not found only in the beauty that pertains to the ear, founded in the movements of bodies, but in the same way is also visible, and because of which we most commonly speak beauty) [St. Augustine 1997: VI, 13, 38, p. 349].

In particular, in Augustine the adjective *numerosus* takes on, in concordance with a long tradition of usage introduced into the Latin language from the writings of Cicero, both the significance of "based on numbers" as well as "harmonious", underlining the link that existed in antiquity between mathematics and beauty.

More than a century later, around 500 A.D., in his *De Istitutione Musica*, Boethius took up the same concept: *Eodem atque modo auris afficitur sonis vel oculus aspectu, quo animi iudicium numeris vel continua qualitate* [Boethius 1867, 1: 32]. So, also for Boethius "the ear is struck by sounds in the identical way that the eye is struck by optic impressions," and that in both cases it is possible to ascertain the same numerical and geometrical harmonies [von Simson 1988: 44].

The philosophy of Scholasticism shared the idea that the musical harmonies governed every beauty of every sort. In his *Theologia Christiana* (1124), Abelard directly linked music to architecture, emphasizing how the fundamental dimensions of Solomon's Temple, found in the Book of Kings, are governed by the harmonic ratios: the length, width, and height of the building are 60, 20 and 30 cubits respectively; those of the cella are 20, 20, and 20 (a perfect cube); the hall 40, 20 and 30 cubits; the portico 20 and 10 [von Simson 1988: 47]. The significance of these dimensions was indicated by the fact that they constitute the exact double of those used by Moses to construct the Tabernacle according to the precise, divine, instructions. It was because of this direct intervention of the Divine in the definition of the design that, for medieval culture, in addition to being the very image of the universe, the Temple was the symbol of the perfect cathedral.[16]

In spite of the myriad difficulties of establishing if these speculations had indeed any concrete effect on architecture, it is clear that Alberti's theory is not the result of individual reflection, based solely on the classical sources that Alberti himself explicitly cites in his treatise,[17] but rather is the summit of an age-old tradition of thought that, during the whole arc of the Middle Ages, had deepened the study of the symbolic and expressive value of harmonic ratios.[18] The paradigmatic confirmation of Alberti that was cited in the opening to this section can be considered a paraphrasing of the text of Boethius as well as the still older one of Augustine.

In *De re aedificatoria*, the harmonic ratios are used to define the limits of architectural elements, which, together with their number and placement, make up, according to Alberti, one of three rules capable of guaranteeing the beauty of any manmade object.[19] The rules have two important fields of application: the determination of areas, and the determination of volumes. Ample space in the treatise is given to the construction of rectangular areas having sides in particular ratios [Alberti 1999: Bk. IX, ch. 6, 306-309].

The harmonies that Alberti uses to give structure to his theory of harmonic areas are those of the Pythagorean scale, the only ones that were deemed valid in medieval

musical theory.[20] In *De re aedificatoria*, Alberti does not linger over a complete description of musical theory-stating that, in its complexity it is beyond the scope of his treatise-but rather limits himself to listing the principle ratios [Alberti 1999: Bk. IX, ch. 6, 305]:

- The fifth, the interval between Do and Sol, defining an interval of five tones, expressed by the ratio 3:2, which in ancient Latin nomenclature of fractions was defined as *sesquialtera*, meaning one and a half;
- The fourth, the interval between Do and Fa, defining an interval of four notes, expressed by the ratio 4:3, in Latin *sesquitertia*, or one and a third;
- The eighth, the interval between the Do that opens the musical scale and the Do of the next successive octave, expressed by the ratio 2:1, in Latin *dupla*, or double;
- The triple, 3:1;
- The quadruple, 4:1;
- The tonus, although not a proper interval, is an essential in the definition of the Pythagorean scale, 9:8, in Latin *sesquioctavus*, or one and an octave.

Applying these harmonic ratios to the length of the side of a rectangle, Alberti defines a total of nine areas, subdivided into three groups of three areas each (**Fig. 6**). The group of "short areas" comprises the square, the *sesquialtera*, and the *sesquitertia*; the "intermediate areas" comprise the double, the double *sesquialtera*, and double *sesquitertia*; the "long areas" comprise the triple, the double plus the *sesquitertia*, and the quadruple. Alberti's prose, extremely clear and accompanied by simple numbers, leaves no margin of error in the interpretation of the construction of the three areas.

In some of the rectangles obtained, the ratio of the sides corresponds exactly to one of the harmonic ratios, while in other cases the harmonic proportions is applied two times, first to the square and then to the long side of the rectangle so obtained, giving rise to a rectangle whose sides do not correspond to a particular musical ratio, but that is descended from one of these through what Rudolf Wittkower [1998] called "a generation of ratios". It remains for us to establish why Alberti chose some particular sequences of ratios and not others.

Maria Karvouni raises the problem in her essay, "Il Ruolo della Matematica nel *De re aedificatoria* dell'Alberti [1994: 283-284], and resolves it brilliantly by moving the focus of attention from the relationships between the sides of the rectangles to those between the areas and between the rectangles themselves: it is in fact possible to demonstrate that the "short areas" are harmonic consonances of the square, the "intermediate areas" are consonant harmonies of the short areas, and the long areas are consonant harmonies of the intermediate areas.

I believe, however, that this way of setting the problem contains a fundamental error: it presupposes that Alberti chose some predetermined areas at the expense of others. In effect, taking into consideration a square area and applying to its side all the possible composite sequences of due of the three harmonic relationships taken into consideration by Alberti, we obtain nine possible combinations that, in theory, when added to the square and to the areas obtained by applying to the square only one harmonic ratio, constitute a series of thirteen different areas. In actuality, some of these areas are equivalent; in other words, they have the same relationships between their sides, and in consequence only nine areas are obtained by adding none, one, or

two relationships to the square-exactly the nine described in *De re aedificatoria* ([Fig. 7](#)).

If we apply to the base square three instead of two harmonic ratios, we obtain twenty-seven new constructions. Of these, twelve are equivalent to those described in *De re aedificatoria*, ten have a relationship of 4:1 between the longer sides and as a consequence turn out to be too elongated to have a practical application in architecture, and only five, of which three are equivalent, represent areas that are not taken into consideration by Alberti.

The constructions that are the objects of consideration in Alberti's treatise have therefore the extraordinary property of defining recurrent areas in the process of generation of ratios, and are thus used to recap a geometrical procession that, in theory, could be infinite.

Alberti himself seems to have been well aware of the fact that certain sequences of different harmonic relationships can give rise to equivalent rectangles when they describe constructions of double, triple, and quadruple areas [Alberti 1999: Bk. IX, ch. 6, 306]. Further, he has a certain familiarity with combinatorics, as is shown by other of his works, such as *De Componendis Cifris*, which is dedicated to cryptographics [Alberti 1994: viii].[\[21\]](#)

In *De re aedificatoria*, Alberti recommends the use of the musical proportions not only to define areas but to delimit volume as well. Where each area is the result of a sequence of harmonic relationships, it is possible to use one or more elements of the series to delimit the third dimension of the object to be designed, completing in this way its spatial configuration.

## CONCLUSIONS

The present analysis has argued that Alberti's work is the apex of a centuries-old aesthetic and philosophical tradition, as well as to the fact that it constitutes a coherent application of those ideas to a built work architecture. The principles set forth in *De re aedificatoria* are punctually applied to the architecture of the Rucellai Sepulchre, in spite of the fact that solidity and requirements in terms of statics make inevitable the separation of any work of architecture from the Platonic purity of theoretical designs. The Albertian theory of musical proportions would be but an empty intellectual game if it were examined without regard for its main goal, the constant search for concinnitas, intended not only in terms of symmetry or equilibrium, but as a superior universal harmony.

## NOTES

[1] For studies of the Rucellai Sepulchre, see [Bruschi 1961]; [Dezzi Bardeschi 1963, 1966]; [Borsi 1973]; [Rykwert and Engel 1994]; [Tavernor 1998]. [return to text](#)

[2] This was the subject of my doctorate thesis, entitled "www.simboli&architettura.it. Progetto per un sito internet multimediale sui rapporti tra simbolo e architettura: il Sepolcro Rucellai di L.B. Alberti", University of Florence, Faculty of Architecture, 2000. [return to text](#)

[3] The chapel, situated between Via della Spada and Piazza S. Pancrazio, is not open to the public. Whoever wishes to enjoy this splendid and unique architecture has no choice but to attend the mass that

is celebrated there on Saturday afternoons. [return to text](#)

[4] For an ample treatment of the general problems relative to the dating and critical interpretation of the Rucellai Sepulchre, see [Tavernor 1998], which contains an up-to-date bibliography of scholarly studies dedicated to this edifice. [return to text](#)

[5] It has not yet been clarified, partly because of the complex series of events that have involved the Holy Sepulchre over the course of the centuries, if there was any metric correspondence between Alberti's design as executed and the Jerusalem original. It is, however, very probable that there is a conceptual parallel and that any reference to the measurements, in any case made doubtful by the most recent studies (see [Tavernor 1998]) is only purely symbolic. [return to text](#)

[6] It should be noted that, because the Sepulchre is represented in section in the figure, there are no references to the proportional grid that the author intended for application to the door. [return to text](#)

[7] The difference in the percentages of the margins of error of the two constructions, related to similar scales and equal metric errors, underlines how the small dimensions of the Sepulchre can falsify the expression of margins of error expressed in percentages, in as much as even the slightest discrepancies take on an exaggerated importance when compared to the lengths that are decidedly out of scale for this particular work. For this reason I have preferred to emphasize in the course of this study the effective metric consistencies of approximations, although I know that this does not constitute the usual practice for this kind of analysis. [return to text](#)

[8] The approximation of this relationship (equal to 1.6%) could be reduced if we take as a length of reference the cornice that bears the inscription (328 cm). However, I wished to maintain a coherence between the analysis of the front and side elevations, bearing in mind that, given the abundance of cornices, projections and moldings, it would be possible to vary the point of reference from elevation to elevation and that practically any construction could be applied, doing so would invalidate the results of the study. [return to text](#)

[9] For a study of the role of the harmonic ratios in architecture, the point of reference continues to be Wittkower [1998]. [return to text](#)

[10] Every instrument produces sound thanks to the vibration of a chord, a column of air, or a membrane that moves the air and creating sound waves in the same way that a stone, cast into a pond, gives rise to waves in the water. The faster the vibration, the shorter the wave length, and the higher the note that is produced. Given all other factors equal, such as material, tension, and thickness, the speed of vibration is inversely proportional to the length of the vibrating body and this allows us to translate musical phenomena in terms of mathematical ratios between lengths. According to the theory of harmonics set forth by E. Hermoltz [1862] and cited by, among others, Fabio Bellissima [1997], the principle vibration, which expands for the full length of the vibrating body, is accompanied by secondary vibrations, called harmonic, which have a length equal to submultiples of the principle length. Notes having lengths in simple ratios among themselves have more common harmonics and, if played contemporaneously, give rise to a pleasant sound that music theory calls a chord. The euphony of the principle consonances does not therefore depend on taste, but rather on simple laws of physics. In effect, all civilisations, no matter what their diversities may be, base their musical scales on the principle intervals of the octave, fifth and fourth, mathematically expressed by the ratios 1:2, 2:3, and 3:4. Given a sound, the three intervals can be used to define the height of the three successive notes. For example, given an initial Do, the interval of the octave defines the Do of the next higher octave; those of the fifth and fourth define the respectively the intermediate Sol and Fa. In this way between the Fa and the Do is defined an ulterior interval of a fourth, while between Sol and Fa the interval is equal to a tone, or 9:8. Objectively, four notes are too

few to create an infinite range of melodies, and the problem of "filling in" with more notes the intervals of the fourth present at the extremes of the scale wasn't resolved in the same way by different cultures. Some musical theories, such as the Oriental and the Celtic, identify only two notes, giving rise to a pentatonic scale. Western cultures, influenced by Greek musical theory, add four notes, giving rise to a scale composed of seven notes. [return to text](#)

[11] The definition of the Pythagorean scale by ascending fifths is a fascinating process, in which, however, there is an innate error: after having gone through twelve fifths, it should be theoretically possible to define a Do seven octaves above the initial one. However, the note that is obtained diverges from Do by a value that takes the name of "Pythagorean comma" and is equal to  $531441/524288$ . This and other discrepancies from the Pythagorean chords have been well known since antiquity, so that in the sphere of the Greek musical tradition itself were elaborated various alternate scales. For a discussion of the mathematical problems tied to the definition of the Pythagorean scale, see [Conti 2001]. [return to text](#)

[12] The Pythagorean school defined the scale that takes its name by the insertion in every fourth of two intervals of a tone, equal to 1:8, and an interval equal to 243:256. Thus is obtained a scale in which are inherent certain mathematical properties, among which is that already mentioned pertaining to the progression of fifths, but it is capable of expressing only the principle chords, rendering others slightly off-tone. The existence of further chords such as the major third (5:4) and the minor third (6:5) had been known since antiquity and had given rise to the elaboration of the natural scale, in which the intervals of fourths are subdivided into three intervals, equal to 9:8, 10:9, and 16:15. The natural scale, based on ratios in which the numerator is greater than the denominator, is absolutely the most euphonic, in as much as it permits the expression of all possible chords, and is that which we unconsciously use when we sing or tune an instrument "by ear". Described by Ptolemy in his *Libro Armonici* in the second century, it was reintroduced into music theory only in 1558 in the essay *Le Istituzione Armoniche* of the Venetian Zarlino. The preference given by medieval music theory to the Pythagorean scale makes the use of the ratios of the natural chords improbable in the architecture of the Middle Ages or the Renaissance. Starting in 1600 the tempered scale is increasingly apparent, with the octave divided into 12 equal half-tones. This scale expresses in an exact way only the octave (in other words, it is slightly off-tone), but permits the execution of a melody on an instrument beginning with any note without having to retune the instrument, precisely because all the intervals between the notes are the same. Because of this evolution, the influence of mathematics and the numeric symbolism in the problems relative to the tuning of the musical scale decreased, and music was definitively dropped from the mathematical disciplines of the quadrivium. [return to text](#)

[13] For a complete interpretation of the musical references of the *Timaeus*, see the notes to the translation of that work by Cesare Giarratano [Plato 1986: 374-376]. [return to text](#)

[14] In particular I am referring to Calcidius's *Comment on the Timaeus*, which dates to the fourth century, and to the later *Comment on Somnium Sipionis* by Cicero, edited in the fifth century by Macrobius, both of which contain ample references to both Platonic and Pythagorean theory. On the fragmentary nature of the classical sources known in the Middle Ages and their influence on the elaboration of Scholastic philosophy, see [Geymonat 1970, I: 482 and 503]. [return to text](#)

[15] In spite of Augustine's title, his book does not deal with vocal or instrumental music, but with that particular branch of music theory that was known as *de rhythmo*, which dealt with the sequence of long or short vocals on which Greek and Latin poetic metre is based. [return to text](#)

[16] The biblical predilection for harmonic ratios is made evident, among other things, by the choice of the dimensions of the Ark of the Covenant described in Exodus 25:10: God ordered Moses to build a chest of precious cedar that was 1.5 cubits high, 1.5 cubits wide, and 2.5 cubits long. The governing 5:3

ratio constitutes a rough approximation of the golden rectangle ( $5:3=0.6$ , while the golden ratio is an irrational number,  $0.618\dots$ ). [return to text](#)

[17] Perhaps the reader will have noticed the absence in this present paper of references to Vitruvius's *De architectura*, often cited with regards to the classical roots of the relationships between music and architecture. This is not a gross oversight on my part, but a recognition that the long dissertation on music theory by the Pythagorean Aristosseno appears in Vitruvius's Book V only in correlation with the architect's need for sufficient culture to allow him to comprehend and resolve problems of acoustics in connection with theatre design. Neither in this or in other places in the treatise is an aesthetic correlation made explicit between the proportions that underlie musical harmonies and those that are supposed to govern architectural design. [return to text](#)

[18] With regards to this argument there developed, over the course of the last half century, an interesting debate: in his *Architectural Principles in the Age of Humanism*, Wittkower assigns a fundamental role to the musical ratios in the evolutionary process that distinguished Renaissance architecture from the earlier medieval tradition. In *La cattedrale gotica*, Otto von Simson [1988] holds instead that the hypothesis that the musical proportions were not only completely theorised by medieval architecture, but that they were constantly applied. In particular, von Simson explicitly takes Wittkower to task for having underrated the theoretic and applicative continuity between the medieval and the Renaissance [1988: 10, note 3]. On the other hand, Wittkower rebutted this in a successive edition of his book, underlining the difficulty of defining an already accomplished aesthetic system in the sphere of medieval schools and the impossibility of applying theoretic speculation to an architecture whose most notable characteristic is empiricism. [return to text](#)

[19] Alberti, in this and in other passages of his treatise, identifies the concept of beauty with that of *concinntas*, stating that:

"[*concinntas*] runs through man's entire life and government, it moulds the whole of Nature. Everything that Nature produces is regulated by the law of *concinntas*, and her chief concern is that whatever she produces should be absolutely perfect" [Alberti 1999: Bk. 9, ch. 5, 302].

The identification of *concinntas* with the larger concept of cosmic harmony is evident. [return to text](#)

[20] See Wittkower [1998]. In fact, it was only in 1558, with the essay by the Venetian Zarlino that the natural scale would be reintroduced. This choice, made possible in the context of a more general mutation in scientific and philosophic thought, sacrificed the symbolism traditionally tied to the definition of the musical scale, but led to a greater euphony, which had become necessary with the ongoing development of polyphonic music. In parallel with the changes that had come about in music theory, architectural theory as well, beginning with Palladio, introduced the rediscovery of the natural ratios as possibilities for correct design. [return to text](#)

[21] In particular on page xviii, the editor hypothesises that Alberti knew of the works of Raimondo Lullo, a Catalan mystic of the fourteenth century, Kabala scholar and inventor of genuine "combinatoric machines", in order to demonstrate irrefutably the superiority of the Christian faith. [return to text](#)

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## ABOUT THE AUTHOR

**Angela Pintore**, born in Udine in 1972, grew up in Macomer, in the province of Nuoro, Sardinia. She has lived in Florence since 1991. In 1999 she won the national competition for Assistant Museum Technician and began to work part-time at the Galleria Palatina in Palazzo Pitti. In 2001 she earned her degree in Architecture with a thesis entitled "www.simboli&architettura.it. Progetto per un sito internet multimediale sui rapporti tra simbolo e architettura: il Sepolcro Rucellai di L.B. Alberti" (Project for a multimedia Internet site on the relationships between symbol and architecture: the Rucellai Sepulchre of

L.B. Alberti), with thesis advisors M. Bini, G. Conti, and G. Verdiani. In 2003, after a successful collaboration with the architecture studio "A.I.A." (Architetti Ingegneri Associati), she decided to dedicate her time to research. She is presently gathering material for the chair of architectural design of the University of Florence.

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