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The Relationship Between Geometry And Numeric Ratio As An Open Problem In Ledoux's Architecture: A Study Of The Floor Plans Of The Barrières Of Paris

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Abstract

The floor plans of Ledoux's *barrières* of Paris, designed during the 1780s, are described using simple geometric constructions. Based on a study of these geometric constructions and the ratios of their parts, it is suggested here that the architect did not treat geometry or numeric ratio as an ideal model of architecture. Rather, he treated the relationship between geometry and numeric ratio as an open problem foreshadowing the attitude of the modern architect.

Introduction

In the Renaissance, architecture was conceived in the image of a universe, where all natural things and their parts were related to one another by the whole numbers. Consequently, the *commensurability* of measures became a nodal point in the architecture of the Renaissance (Wittkower, 1949). This mathematical precept started losing its importance for the first time in the late 17th century, when Claude Perrault, a founding member of the *Académie Royale des Sciences* in France, noted that no one had been successful in identifying exactly the basis of the precept, nor had anyone been able to imitate the precept perfectly in architecture (Perrault, 1674, 1683). The precept lost its importance even more with the development of such aesthetic concepts as the *sublime* and the *picturesque* in the late 17th and the early 18th century. However, the controversy over the efficacy of commensurable ratios in architecture remained very much alive at the end of the 18th century. Those who upheld the Renaissance ideal suggested that commensurable ratios were important in architecture because it reflected the underlying order of the universe, while others argued that the efficacy of proportion in architecture was only a matter of experiment and experience (Wittkower, 1949; Scholfield, 1958).

During this period of controversy, Ledoux worked as an architect in France. He was fascinated with the *sublime* and the *picturesque* (Vidler, 1990). In several cases, he used these aesthetic concepts as licenses to distort physical forms and to create strong asymmetrical internal layout of architecture enhancing elements of surprise and novelty. As a result, it has been difficult to imagine that any consistent system of proportion, something like that of the Renaissance architecture, might exist in

Ledoux's architecture. Though a term like "Palladianism" is frequently used to characterize his architecture (Vidler, 1990), the role of commensurable ratios, a very important element of the Renaissance architecture, remains unknown in Ledoux's architecture.

This is despite the fact that Ledoux was familiar with the classical theories of beauty and had kept the treatises by Vitruvius, Palladio, Serlio, and Inigo Jones in his small library of some two hundred twenty volumes of books (Vidler, 1990: 377). Like his Renaissance predecessor, Ledoux was convinced, at least in theory, that everything in art must abide by the eternal laws of nature (*Architecture de C N Ledoux*, Premier Vol., trans. Vidler, 1983: xi). However, Ledoux made no explicit reference in his writings to the distinction between commensurable and incommensurable ratios, and to the importance of commensurable ratios in architecture. Is it possible that Ledoux used commensurable ratios in his designs even though he failed to mention their importance in his writings?

The geometric constructions of Ledoux's *barrières* of Paris

In order to find out Ledoux's attitude to commensurable ratios, the floor plans of the *barrières* of Paris designed by the architect for the *Ferme Gènèrale* (or the royal general tax farm), between 1784 and 1789, were studied. These *barrières* were designed for some forty-five entrances of the new boundary wall of the city. A typical *barrière*, as noted by Vidler (1990), provided living and sleeping quarters for a brigade of seven to eight guards, and an *avant-garde* of four or five, plus their *brigadier*, rooms for a clerk or receiver, as well as a kitchen, an office, and a cellar for wine and wood storage. Separate sentry boxes were provided for the officers on duty. For larger entrances, warehouses and *dépôts* for confiscated goods, custom shed, stable, and carriage houses were also provided.

Since most of these *barrières* were already demolished by 1859 (Vidler, 1990), the floor plans of the *barrières* published in the book *Architecture de C N Ledoux* (1983) were used in this study. These floor plans were subjected to geometric constructions. The proportions of the floor plans were then determined from the geometric constructions that described the location of their walls in a consistent manner. It can be noted here that, since in a geometric construction every element is related to every other element by some geometric moves, it is impossible to modify the dimension of an element without changing the dimensions of all other elements of the construction.

The geometric constructions of the floor plans of all 23 *barrières* included in the book are provided in the figures in **Appendix 1**. In the appendix, the floor plans of the *barrières* are numbered according to the plate number of the book *Architecture de C N Ledoux* (1983). For example, the floor plan on plate-1 of the book is indexed as Ledoux-1; the floor plan on plate-3 of the book is indexed as Ledoux-

3; and so on. For each floor plan, first, the geometric construction is shown directly on the floor plan allowing the reader to observe the degree of match between the plan and the *parti* defined by the construction. Then, the construction is shown separately with the number and sequence of geometric moves involved in the construction. For each floor plan, the important elements of the *parti* are also shown in a separate diagram.

It can be observed from the diagrams that a *parti* defined by a simple construction of circles and straight-lines describes, quite accurately, the positions of almost all the walls in each floor plan. However, the positions of the walls in relation to the *parti* lines are not always the same in these plans: In some floor plans, the *parti* lines follow the centerlines of the walls (Ledoux-8, 15, 23, 24, 34, & 36); in some, they follow the exterior sides of the walls (Ledoux-1, 3, 9, 10, &17); in some others, they follow the interior side of the walls (Ledoux-5, 12, & 20); and in the rest of the floor plans, the *parti* lines are located ambiguously in relation to the walls (Ledoux-6, 21, 22, 26, 28, 30, 32, 33, & 35).

Despite the above inconsistencies, the degree of match between each floor plan and its *parti* defined by a geometric construction is quite remarkable suggesting that a constructional logic may exist for each floor plan. According to this logic, the differences in the geometric processes describing the floor plans may be an explanation for the differences in their compositions. For example, in some plans, the geometric constructions proceed from the center to the periphery (Ledoux-5, 6, 8, 12, 15, 24, 30, 32, 33, 34, 35); in some others, they proceed from the periphery to the center (Ledoux-9, 10, 17, 20, 21, 22, 23, 26, 28, 36); and in the rest, they proceed to the center and periphery simultaneously beginning somewhere in the middle of the constructions (Ledoux-1, 3).

There are, however, more important differences in the processes of geometric constructions of the floor plans of the *barrières*. Some geometric constructions involve only the divisions and sub-divisions, and/or the multiples and sub-multiples of a diameter of the first circle. As a consequence, in these constructions the relationships of the parts to each other and to the whole are defined by commensurable ratios. In contrast, the other constructions involve the diagonals of circumscribing squares, and/or the sides of inscribing squares of the first circle and/or its derivative circles. As a consequence, in these constructions the relationships of the parts to each other and to the whole are defined by incommensurable ratios, or by both commensurable and incommensurable ratios.

The analysis of the numeric ratios of the *barrières*

The ratios of the floor plans of the *barrières*, determined from their geometric constructions, are given in column-2 of **Table 1**. As identified in column-3, among these ratios, there are the commensurable and incommensurable ratios, as well as the harmonic and non-harmonic or aharmonic ratios. The root-ratios shown in column-2 are converted to their nearest commensurable ratios in column-4. The revised types of ratios in column-5 now include the nearest commensurable ratios of the root-ratios. In column 6, the ratios mentioned by Vitruvius, Alberti, and Palladio in their texts are identified.

It can be noted here that there are at least four different tuning systems - Pythagorean, Tempered, Just, and Archytus - to generate harmonic ratios. For the Pythagorean and Tempered systems, the generators of harmonic ratios are 2 and 3, i.e., 2^p3^q; for the Just system, they are 2, 3 and 5, i.e., $2^p3^q5^r$; and for the Archytus system, they are 2, 3, 5, and 7, i.e., $2^p3^q5^r7^s$ (McClain, 1978).[1] Though numerous ratios can be generated using the generators of these systems, the ratios of any two whole numbers of the following set defined by the Archytus system were used in **Table 1** for the purpose of this study: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 15, 16, 18, 20, 21, 24, 25, 27, 28, 30, 32, 35, 36, 40, 42, 45, 48, 49, 50, 54, 56, 60, 63, 64, 70, 72, 75, 77, 80, 81, 84, 90, 91, 96, 98, and 100. The ratios generated by these numbers also include the ratios of the other three systems, since they include any whole number smaller than 100 that can be generated by 2, 3, and/or 5. In addition to the ratios generated by the above numbers, $1:\sqrt{2}$ (the augmented fourth, i.e., the fourth plus a semitone)[2] from the equal tempered scale was also used as a harmonic ratio in the study.

Among the writers of the classical architectural treatises, Vitruvius mentioned 1:2 (the octave), 2:3 (the perfect fifth), 3:5 (the major sixth), and $1:\sqrt{2}$ in relation to room dimensions (Vitruvius, *Ten Books*, Book VI. ii. 8, 1960: 189). Since the equally "tempered" scale was not known to Vitruvius, the

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[1] Except the Tempered scale, all other tuning systems are archaic. Invented by Vicenzo Galilei, the Tempered scale was introduced in the 16th century by Gioseffe Zarlino (McClain, 1978: 173, 175; *The Oxford Dictionary of Music*, 1985: 805). Already before Ledoux began his career in architecture, Bach (1685-1750) had successfully integrated the old systems with the Tempered scale in his music.

It can be mentioned here that, in the previous studies on the use of harmonic ratios in architecture only 2,3, and 5 are used as the generators of harmonic ratios (e.g., Wittkower, 1949; Scholfield, 1958; Howard and Longair, 1982; Mitrovic, 1990; March, 1996). These studies give no reason for not using 7 as a generator of harmonic ratio. However, 6:7 (septimal third) and 7:8 (septimal second or septimal tone) of the Archytus scale are important musical intervals and can be heard frequently in the music of instruments which depend wholly on the harmonic series for their notes, as with the older brass instruments (Baines, 1983).

[2] In an equal tempered scale, an octave space is divided into twelve equal parts, so that a "semitone" of 1/12th of the octave has the numerical value $\sqrt[12]{2}$. In this scale, $1:\sqrt{2}$ is a fourth augmented by a semitone for the following reason: $1:\sqrt{2} = 1:\sqrt[12]{2}^6 = 1:(\sqrt[12]{2}^5 \times \sqrt[12]{2}) \approx 1:(4/3 \times 18/17)$.

importance given to 1: √2 by him must have to be explained by the fact that it is the ratio of the side of a unit square to its diagonal. Alberti mentioned three groups of ratios for three different room shapes in his treatise. For short areas, he mentioned 1:1 (the unison), 2:3 (the sesquialtera, or the diapente, or the perfect fifth), 3:4 (the sesquitertia, or the diatesseron, or the perfect fourth); for intermediate areas, 1:2 (the diapason, or the octave), 4:9 (the double sesquialtera, i.e., $2^2:3^2$), and 9:16 (the double sesquitertia, i.e., $3^2:4^2$); and for long areas, 1:3 (the triple, or the diapason diapente, i.e., 1:2 x 2:3), and 3:8 (a double enlarged by a sesquitertia, or the diapason diatesseron, i.e., 1:2 x 3:4) (Alberti, *Ten Books*, Book IX, Chap. vi, 1988: 306). In his treatise, Palladio mentioned the circle, the square, 1:√2, 3:4, 2:3, 3:5, and 1:2 for room shapes (Palladio, *Four Books*, Book I, Chap. xi, 1965: 27). Again, it is not known whether Palladio was aware of the musical significance of 1:√2 (Howard and Longair, 1982; Mitrovic, 1990). Probably, he used the ratio for the same reason Vitruvius had used it before him.

According to the data provided in columns 2 & 3 of **Table 1**, 9 out of 23 *barrières* (approximately 40%) have only commensurable ratios; 7 *barrières* (approximately 30%) have only incommensurable ratios and the other 7 *barrières* (approximately 30%) have both commensurable and incommensurable ratios. And, out of all 62 ratios used in the floor plans of all 23 *barrières*, 31 ratios (50%) are commensurable, and 31 (50%) are incommensurable ratios. These findings may suggest that commensurable and incommensurable ratios, as well as the relationship between these two kinds of ratios, were treated as important aspects in the design of these *barrières* by Ledoux.

According to the data provided in columns 2 & 3 of **Table 1**, harmonic ratios also appear to be particularly important for the floor plans of these *barrières*. At least 10 *barrières* (approximately 43%) have only harmonic ratios; and out of all 62 ratios used in 23 *barrières*, 35 ratios (approximately 56%) are harmonic. When incommensurable ratios are converted to their nearest commensurable ratios (see column-5 of **Table 1**), the number of *barrières* with only the harmonic ratios increases to 19 (approximately 83%); and the total number of harmonic ratios increases to 57 (approximately 92%). Also note that out of 31 incommensurable ratios 27 (approximately 87%) are harmonic in approximation. These findings may indicate that Ledoux might have used the floor plans of the *barrières* to investigate and understand the relationship between geometry and harmonic ratios, as well as the effects of the minute variations of harmonic ratios in architectural aesthetics.

In addition, Vitruvius, Alberti and Palladio mentioned 20 out of 35 harmonic ratios (57%) found in the geometric constructions of the floor plans of the *barrières*. If the nearest harmonic ratios of the incommensurable ratios are considered, then 24 out of 57 harmonic ratios (42%) are mentioned by Vitruvius, Alberti and Palladio. Since it is possible to generate a vast number of harmonic ratios using 2, 3, 5, and 7, a very high occurrence of the harmonic ratios mentioned by Vitruvius, Alberti, and Palladio in Ledoux's *barrières* should not be explained away as fortuitous.

	Column-2	Column-3	Column-4	Column-5	Column-6
	Ratios	Ratio Types	Nearest commensurable ratios of the root ratios	Revised Ratio Types	Used in the following classical texts
Ledoux 1	$x_1:y_1 = 2:5$	C, H		C, H	
	$x_2:y_3 = 3:5$	C, H		C, H	V, P
	$x_3:y_1 = 8:5$	C, H		C, H	
	$x_4:y_2 = \sqrt{2}:1$	I, H_t	7:5	C, H_a	V, P
Ledoux 3	$x_1:x_2 = 4:5$	C, H		C, H	
Ledoux 5	$x_1:y_1 = 8:3$	C, H		C, H	A
	$x_2:y_2 = 1:\sqrt{5}$	I, AH	4:5	C, H	
	$x_3:y_1 = 16:9$	C, H		C, H	A
	$x_4:y_3 = \sqrt{2}:1$	I, H_t	7:5	C, H_a	V, P
Ledoux 6	$x_1:y_1 = 1:\sqrt{2}$	I, H_t	5:7	C, H_a	V, P
Ledoux 8	$x_1:x_6 = 1:2/(\sqrt{2}-1)$	I, AH	5:24	C, H	
	$x_2:x_6 = 1:2/(\sqrt{3}-\sqrt{2}+1)$	I, AH	2:3	C, H	V, A, P
	$x_5:x_6 = 1:2/(\sqrt{5}-\sqrt{2}+1)$	I, AH	1:1	C, H	V, A, P
	$x_3:x_6 = 1:2/(\sqrt{5}-1)$	I, AH	5:8	C, H	
Ledoux 9	$x_1:y_1 = 2:1$	C, H		C, H	V, A, P
	$x_2:y_3 = 1:\sqrt{3}$	I, AH	4:7	C, H_a	
	$x_1:y_2 = 2:5$	C, H		C, H	
Ledoux 10	$x_1:x_2 = 1:(\sqrt{2}+1)/(\sqrt{2}-1)$	I, AH	6:35	C, H_a	
	$x_1:x_3 = 1:3$	C, H		C, H	A
Ledoux 12	$x_1:x_2 = 1:3$	C, H		C, H	A
	$x_1:x_3 = 2:9$	C, H		C, H	
Ledoux 15	$x_1:x_2 = 1:(3-\sqrt{2})$	I, AH	5:8	C, H	
	$x_1:x_3 = 1:2(\sqrt{2}-1)$	I, AH	6:5	C, H	
	$x_1:x_4 = 1:(\sqrt{2}-1)$	I, AH	5:2	C, H	
Ledoux 17	$x_1:y_1 = 7:8$	C, H_a		C, H_a	
	$x_2:y_1 = 5:8$	C, H		C, H	
	$x_3:y_1 = 3:2$	C, H		C, H	V, A, P
Ledoux 20	$x_1:x_2 = 3:4$	C, H		C, H	A, P
	$x_1:y_1 = 1:2$	C, H		C, H	V, A, P
	$x_1:y_2 = 3:7$	C, H_a		C, H_a	
Ledoux 21	$x_1:x_2 = 4:7$	C, H_a		C, H_a	
	$x_1:x_3 = 1:4$	C, H		C, H	
Ledoux 22	$x_1:x_3 = 3:8$	C, H		C, H	A
	$x_2:x_3 = 5:8$	C, H		C, H	

	Column-2	Column-3	Column-4	Column-5	Column-6
	Ratios	Ratio Types	Nearest commensurable ratios of the root ratios	Revised Ratio Types	Used in the following classical texts
	$x_3:x_5 = 8:13$	C, AH		C, AH	
Ledoux 23	$x_1:y_3 = 1:4$	C, H		C, H	
	$x_5:y_3 = \sqrt{3}:1$	I, AH	7:4	C, H_a	
	$x_4:y_2 = 1:(4+\sqrt{3})/(4\sqrt{3}-1)$	I, AH	1:1	C, H	V, A, P
	$x_3:y_1 = 1:(4-\sqrt{3})/4(\sqrt{3}-1)$	I, AH	9:7	C, H_a	
	$x_3:y_3 = 1:1/(\sqrt{3}-1)$	I, AH	3:4	C, H	A, P
Ledoux 24	$x_1:x_2 = 1:\sqrt{2}$	I, H_t	5:7	C, H_a	V, P
	$x_4:x_3 = 1:(1+2\sqrt{2})$	I, AH	6:23	C, AH	
	$x_4:x_2 = 1:(2+2\sqrt{2})$	I, AH	6:29	C, AH	
Ledoux 26	$x_1:x_2 = 1:(1+2\sqrt{2})/\sqrt{2}$	I, AH	1:2	C, H	V, A, P
	$x_1:x_3 = \sqrt{2}:1$	I, H_t	7:5	C, H_a	V, P
	$x_3:x_2 = 1:(1+2\sqrt{2})$	I, AH	6:23	C, AH	
Ledoux 28	$x_3:y_2 = 1:\sqrt{(10-4\sqrt{2})}/\sqrt{2}$	I, AH	2:3	C, H	V, A, P
	$x_1:y_2 = 1:\sqrt{(10-4\sqrt{2})}$	I, AH	1:2	C, H	V, A, P
	$x_2:y_1 = 1:\sqrt{(10-4\sqrt{2})}/(2+\sqrt{2})$	I, AH	8:5	C, H	
Ledoux 30	$x_1:x_3 = 4:9$	C, H		C, H	A
	$x_1:x_2 = 8:5$	C, H		C, H	
Ledoux 32	$x_1:x_2 = 1:\sqrt{(6\sqrt{2}-2)}/2$	I, AH	11:14	C, AH	
	$x_1:x_3 = 1:\sqrt{(6\sqrt{2}+2)}/2$	I, AH	5:8	C, H	
Ledoux 33	$x_1:x_2 = 2:3$	C, H		C, H	V, A, P
	$x_1:x_4 = 1:\sqrt{5}$	I, AH	4:5	C, H	
	$x_1:x_3 = 1:\sqrt{14}/2$	I, AH	15:28	C, H_a	
Ledoux 34	$x_1:y_1 = 5:18$	C, H		C, H	
	$x_2:y_1 = 4:9$	C, H		C, H	A
Ledoux 35	$x_1:x_2 = 2:3$	C, H		C, H	V, A, P
	$x_1:x_3 = 1:4$	C, H		C, H	
Ledoux 36	$x_1:y_1 = 1:1$	C, H		C, H	V, A, P
	$x_1:y_2 = 1:(4-\sqrt{3})/2$	I, AH	7:8	C, H_a	

Table 1: Important ratios found in the geometric constructions of the floor plans of the *barrières* of Paris designed by Ledoux.

[Legends: C = Commensurable. I = Incommensurable. H = Harmonic. H_t = Harmonic in the equally "tempered" scale. H_a = Harmonic in the Archytas scale. AH = Aharmonic. V = Vitruvius. A = Alberti. P = Palladio.]

Conclusion

It is not assumed here that Ledoux had used any particular method of geometric construction of circles and straight lines to design the *barrières* of Paris. In fact, alternative methods of geometric construction may exist for several of these *barrières*. However, when it is realized that the architect was required to design a large number of *barrières* within a very short period of time, the usefulness of a simple method of geometric constructions in the process of design becomes obvious. A simple geometric system would have allowed him to easily create compositional patterns of different kinds. It would have also allowed him to ensure a consistent relationship of the parts to each other and to the whole in his designs.

The use of geometric constructions as an aid to design is not without precedents in architecture. Interests in the construction of circles and squares in architecture probably originated in Plato (*Timaeus* 33B; *Meno*, 82B-85B). Vitruvius made reference to the geometric constructions of circles and squares in relation to the human body in the following passage:

> . . . in the human body the central point is naturally the navel. For if a man be placed flat on his back, with his hands and feet extended, and a pair of compasses centered at his navel, the fingers and toes of his two hands and feet will touch the circumference of a circle described there from. And just as the human body yields a circular outline, so too a square figure may be found from it. For if we measure the distance from the soles of the feet to the top of the head, and then apply that measure to the outstretched arms, the breadth will be found to be the same as the height, as in the case of plane surfaces which are perfectly square (Vitruvius, *Ten Books*, Book III, Chap. 1.3, trans. Morgan, 1960: 73).

The Renaissance architect showed a great deal of interests in the geometric constructions of circle and square, particularly in the design of centrally planned churches (Wittkower, 1949). Earlier, the medieval architect had also used geometric constructions, but with a very different attitude: "the medieval artist tends to project a pre-established geometrical norm into his imagery, while the Renaissance artist tends to extract a metrical norm from the natural phenomena that surround him" (Wittkower, orig. 1949, 1971: 159). In other words, while the medieval architect used geometry as an end in design, the Renaissance architect used it merely as a means to achieve the end. For the Renaissance architect, the end was probably the harmonic ratios of metrical measures.

Ledoux did not use the geometric construction as a representation of the universal unity in the way the medieval architect would have used it. As noted before, though the *parti* defined by a geometric construction was able to describe the placement of walls in the floor plans of the *barrières*, the placement of walls in relation to the *parti* was not always consistent in these plans. In other words, even if it were true that the architect used geometry as the generator of design, he certainly was not enslaved by it. He had taken the liberty to modify the positions of the walls in relation to the *parti* using other criteria. Ledoux would not have taken this liberty if he had treated geometry as the end in his design.

Neither did Ledoux use only commensurable ratios in the floor plans of the *barrières* in the way the Renaissance architect would have used it. As the study showed, he not only mixed commensurable with incommensurable ratios in his floor plans of the *barrières*, in a large number of these floor plans he used only incommensurable ratios, which his Renaissance counterpart would not have approved.

It seems that the findings of this study can be explained only if the architect held an equal interest in geometry and harmonic ratios. That he never used geometry and harmonic ratios as totally separate aspects in his *barrières* was proven by the fact that most of the incommensurable ratios derived from geometric constructions were harmonic when converted to their nearest commensurable ratios. Ledoux's tendency to experiment with the limits of geometry and numeric ratios in the floor plans of the *barrières* probably reflected his tendency to experiment with the same in the physical form of the *barrières* already observed by others (Kaufmann, 1943; Vidler, 1984, 1990). This thesis is not far-fetched given Vidler's proposition that Ledoux took his inspirations from more recent quasi-scientific investigations into the psychological and behavioral interpretation of physiognomy (Vidler, 1990: 206-207). "This "science," Vidler writes:

> elaborated by the Swiss pastor Johann Caspar Lavater between 1775 and 1778, was based on the premise, stated in his *Essays in Physiognomy*, that "the exterior, the visible, the surface of objects indicate their interior, their properties; every external sign is an expression of internal qualities"; and that by careful analysis of the "characteristic lines," the contours and surfaces of a face, the nature of the soul within might be discovered (Vidler, 1990: 206).

According to this science, if in order to express two very different functions - habitation and transition - in the physical form of the *barrière*s, Ledoux had experimented with the established canons of physical form, then his experiments with geometry and numeric ratios in the internal layout of the *barrières* was an indication of it, and vice versa. The medieval architect could not have shown such an experimental attitude towards geometry, because he was taken over too much by the power of its universal image. Likewise, the Renaissance architect could not have shown such an experimental attitude toward numeric ratios, which, for him, represented the order of the universe. Ledoux freed geometry and numeric ratios from these preconceptions, while maintaining their theoretical importance. As a consequence, he was able to treat the relationship of geometry and numeric ratio as an open problem in architecture foreshadowing the modern attitude to these elements, as discussed by Wittkower (orig. 1949, repr. 1971) and Scholfield (1958).

References:

Alberti L B (repr. 1988): *On the art of building in ten books*, translated by Joseph Rykwert, Neil Leach, and Robert Tavernor, Cambridge, Mass.: MIT Press.

Baines A (1983): "Harmonic series," *The New Oxford Companion to Music*, Oxford: Oxford University Press.

Howard D, Longair M (1982): "Harmonic proportion and Palladio's Quattro libri," *Society of Architectural Historians. Journal*, May, v.41, n.2, p.116-143.

Kaufmann E (1943): "Claude-Nicolas Ledoux: Inaugurator of a new architectural system," *Society of Architectural Historians. Journal (JSAH)*, July, vol. 3, no. 3, p. 12-20.

Ledoux C-N (1983): *Architecture de C N Ledoux*, Premier vol., Princeton: Princeton Architectural Press.

March L (1996): "Renaissance mathematics and architectural proportion in Alberti's *De re aedificatoria*," *ARQ*, vol. 2, Autumn, p. 54-65.

McClain E G (1978): *The Pythagorean Plato: Prelude to the song itself*, Stony Brook, N.Y.: Nicolas Hays, Ltd.

Mitrovic B (1990): "Palladio's theory of proportions and the second book of the Quattro libri dell'architettura," *Society of Architectural Historians. Journal*, Sept., v.49, no.3, p.279-292.

Palladio A (1738, repr. 1965): *Four Books of Architecture*, trans. by Issac Ware, New York: Dover Publications.

Perrault, Claude (1674, trans. 1692): *An Abridgment of the Architecture of Vitruvius . . . First done in French by Monsr Perrault . . . and Englished with Additions*, London.

Perrault, Claude (1683, reprint 1708): *A treatise on five orders of columns in architecture*, trans, in English by John James, London: J. Stuart.

Plato (1997): *Timaeus*, trans. by Benjamin Jowett, 1st edition, Prentice Hall.

Plato (1976): *Meno*, trans. by G. M. A. Grube, 2nd edition, Hackett Publishing Company.

Scholfield P H (1958): *The Theory of Proportion in Architecture*, Cambridge: Cambridge University Press.

Wittkower R (orig. 1949, repr. 1971): *Architectural principles in the Age of Humanism*, London: W W Norton & Company.

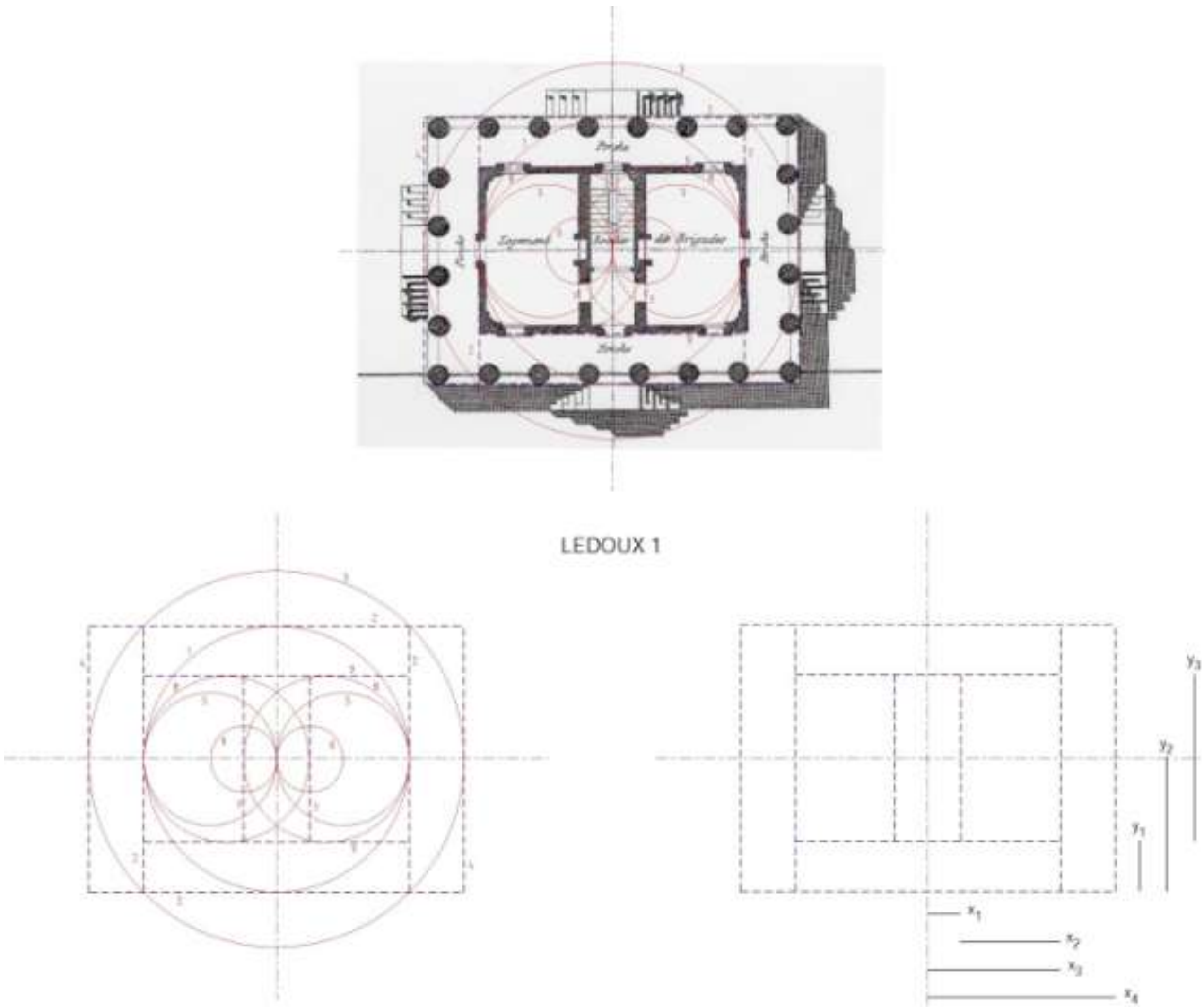
Vidler A (1984): "The rhetoric of monumentality: Ledoux and the barrières of Paris," *AA files*, Sept., no.7, p.14-29.

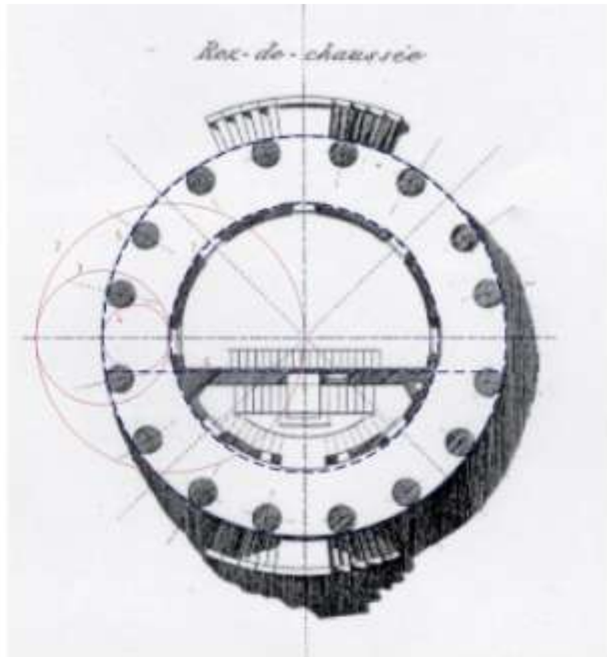
Vidler A (1990): *Claude-Nicolas Ledoux*, Cambridge, MA: MIT Press.

Vitruvius (1960): *The Ten Books on Architecture*, trans. by Morris Hicky Morgan, New York: Dover Publications.

Appendix 1

The Relationship Between Geometry And Numeric Ratio As An Open Problem In Ledoux's Architecture: A Study Of The Floor Plans Of The Barrières Of Paris





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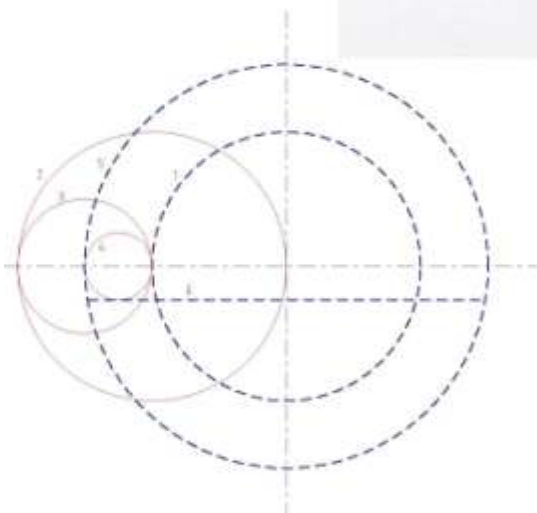

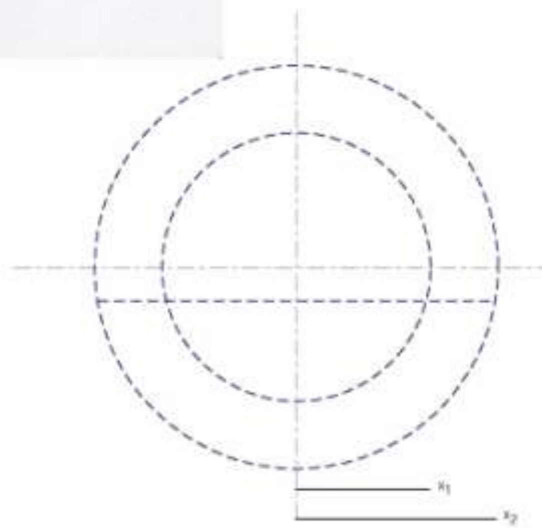

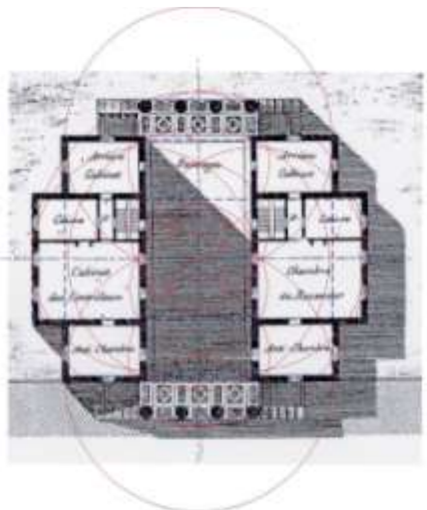

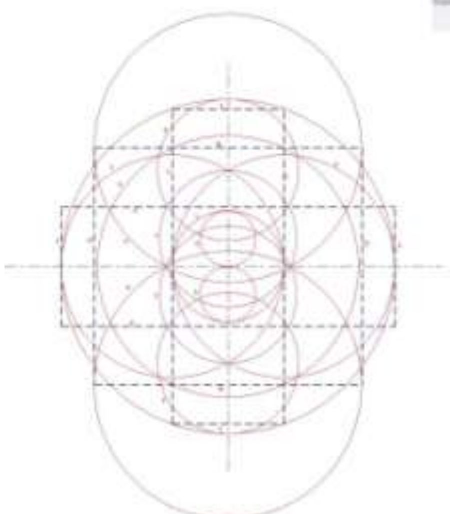

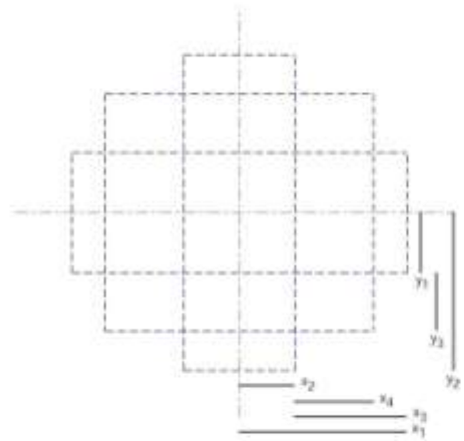

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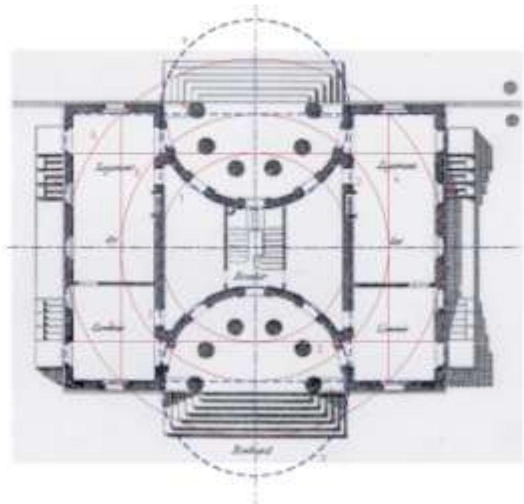

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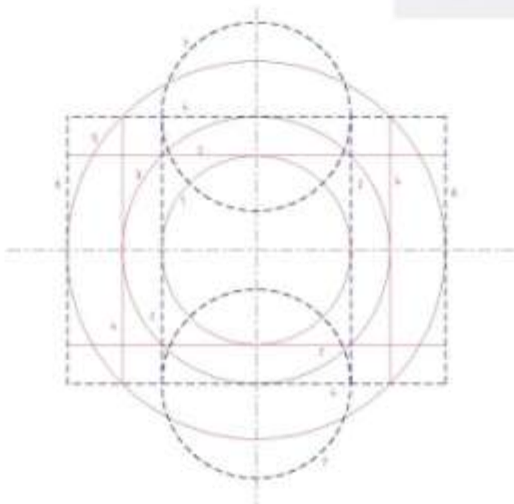

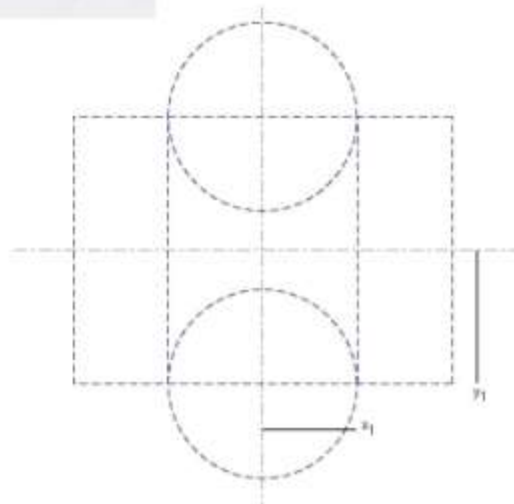

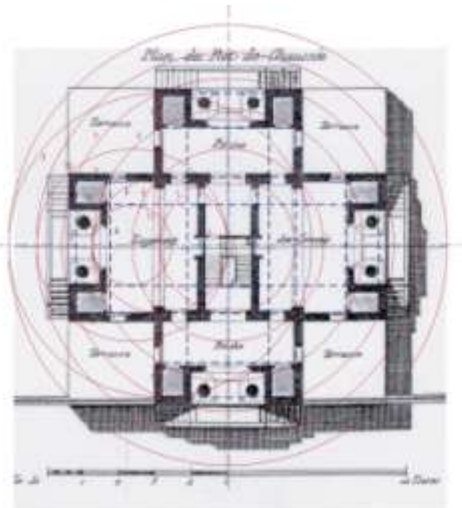

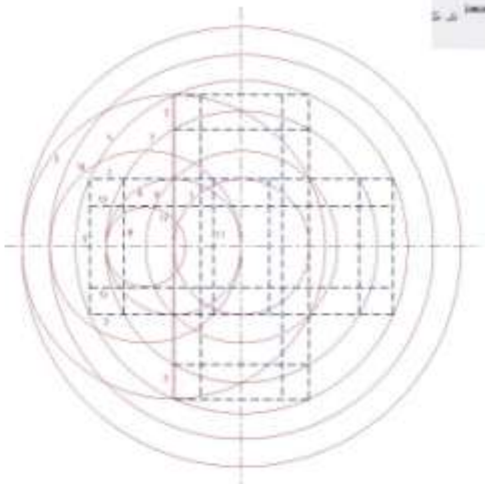

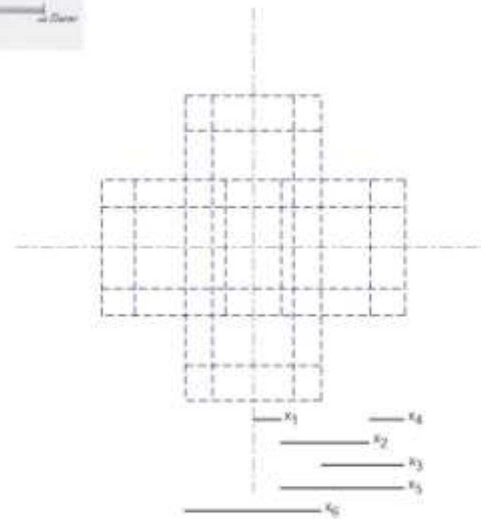

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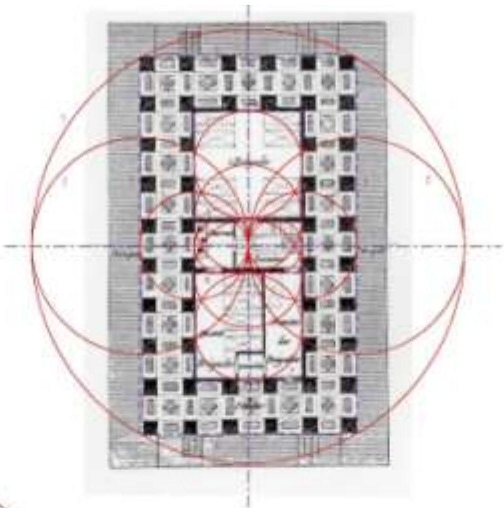

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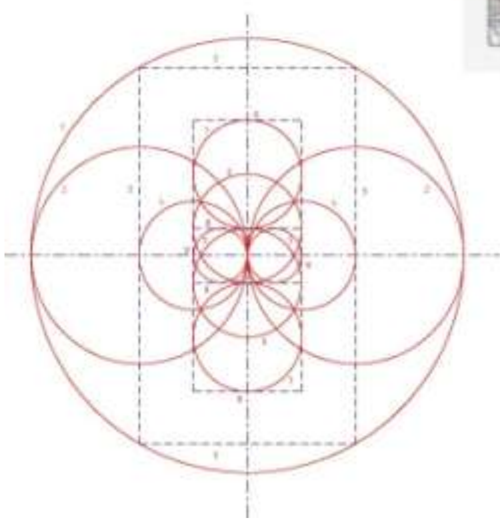

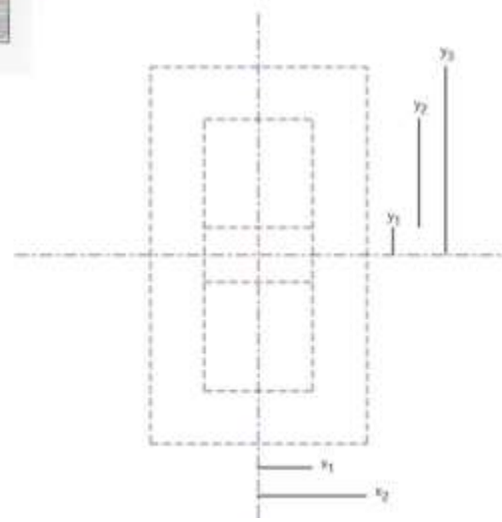

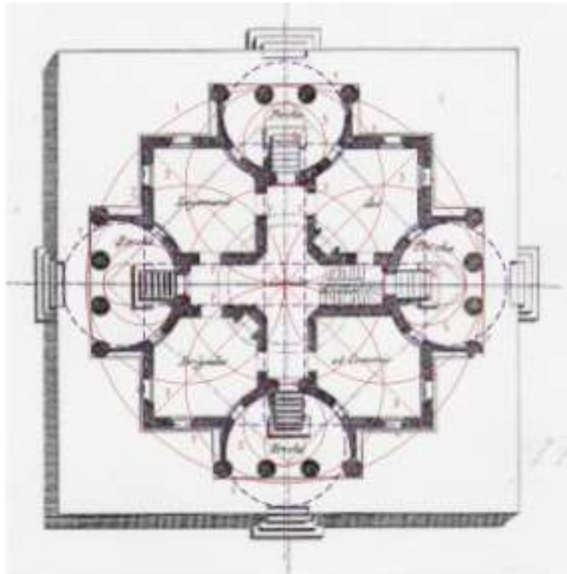

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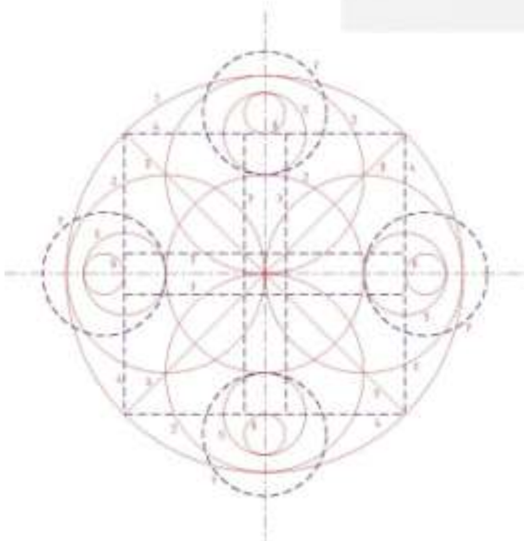

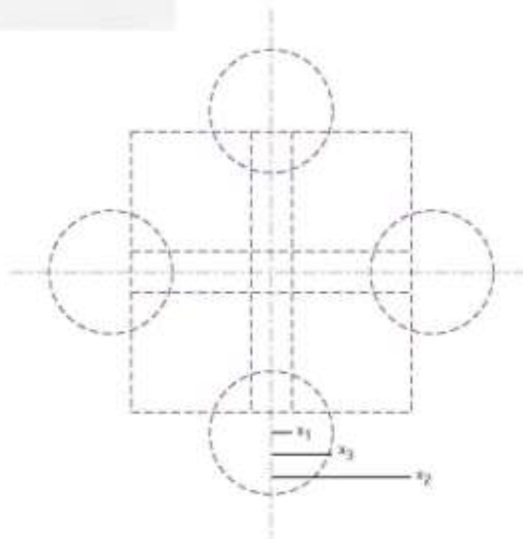

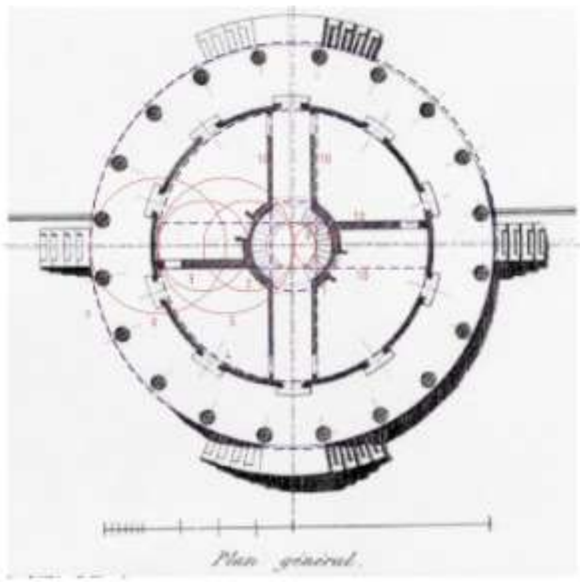

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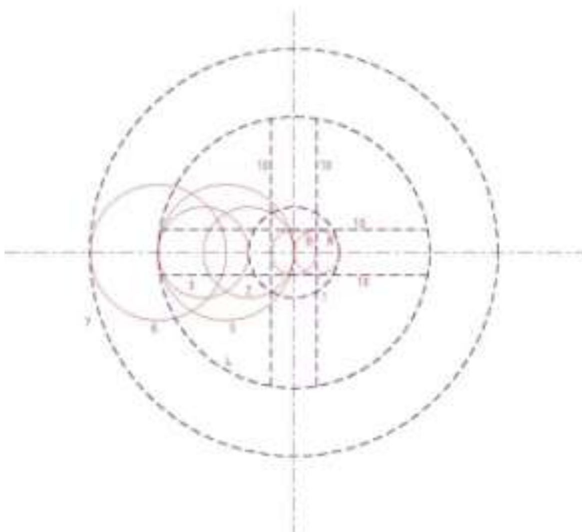

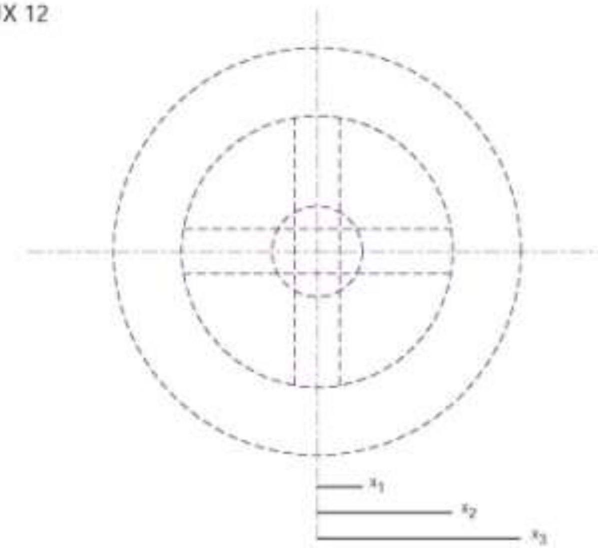

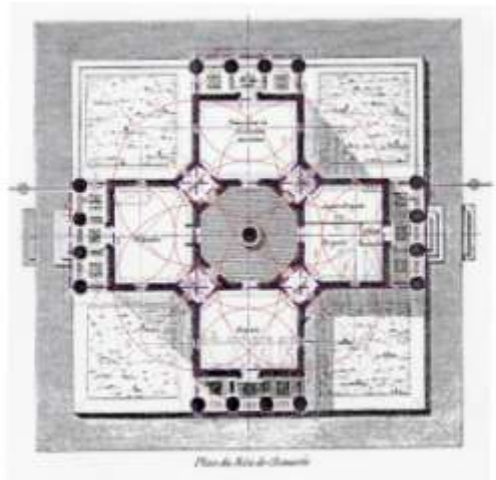

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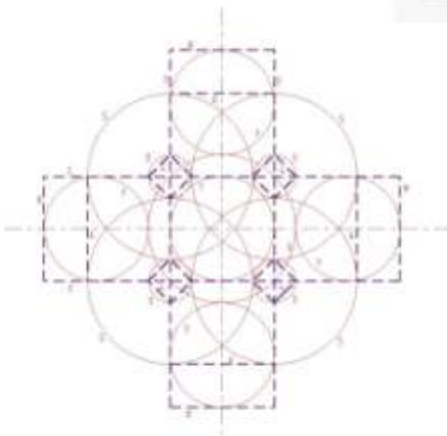

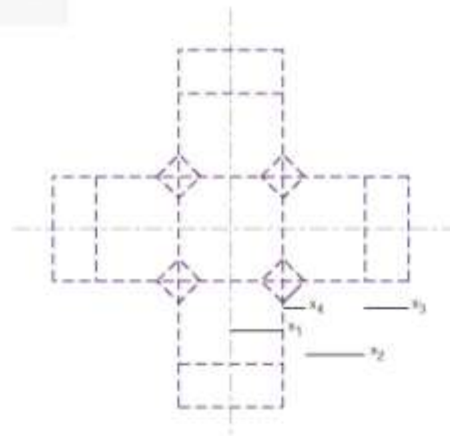

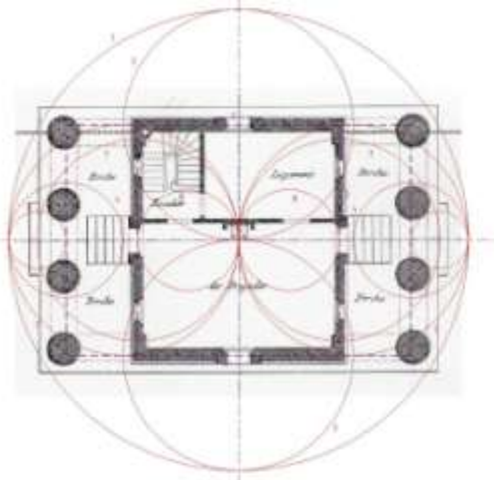

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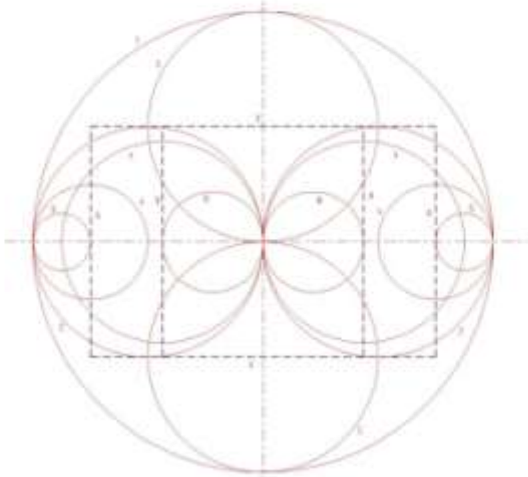

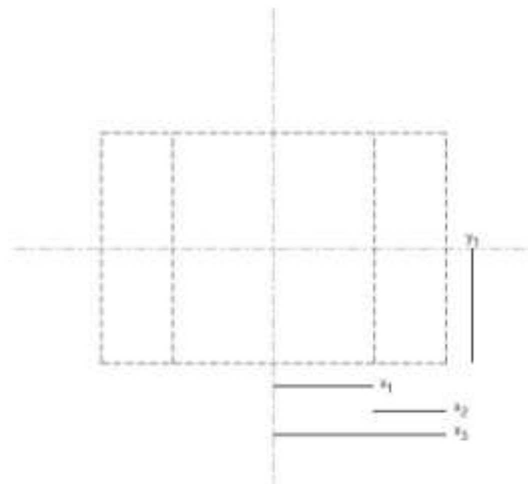

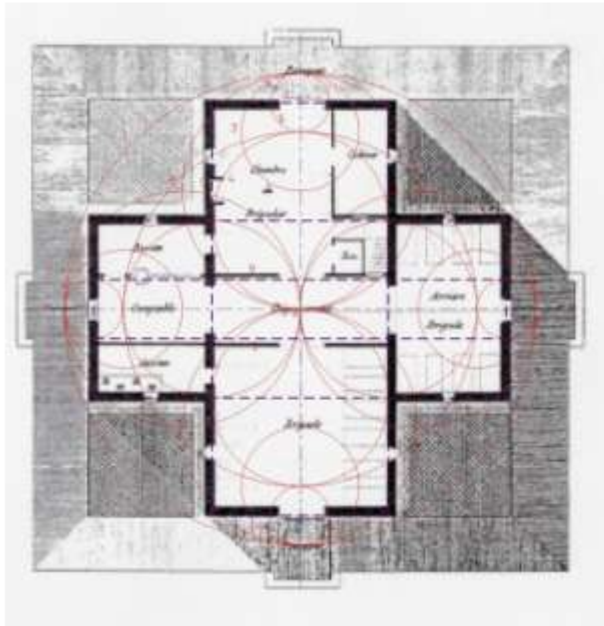

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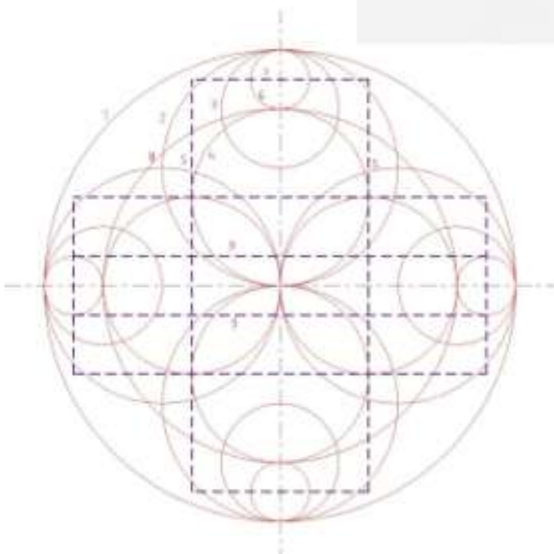

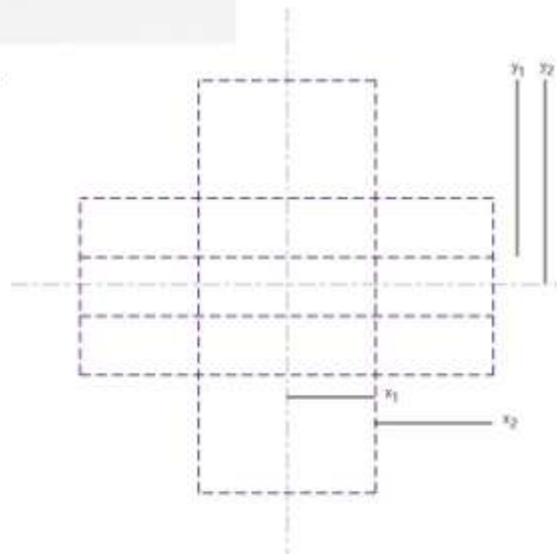

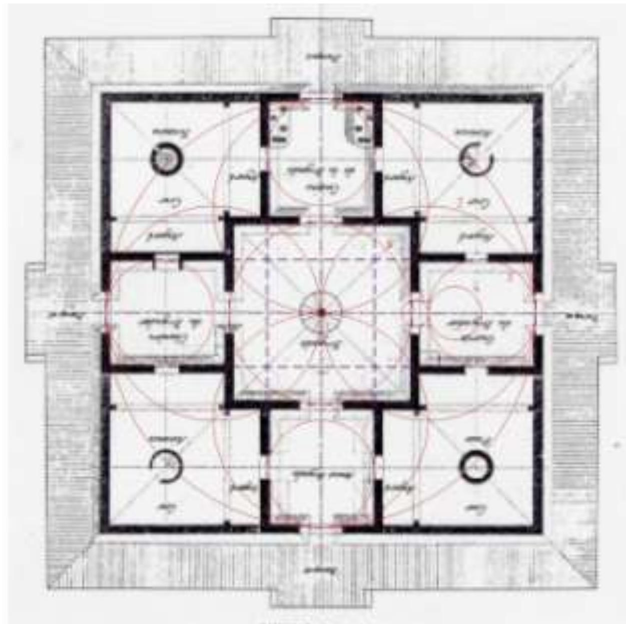

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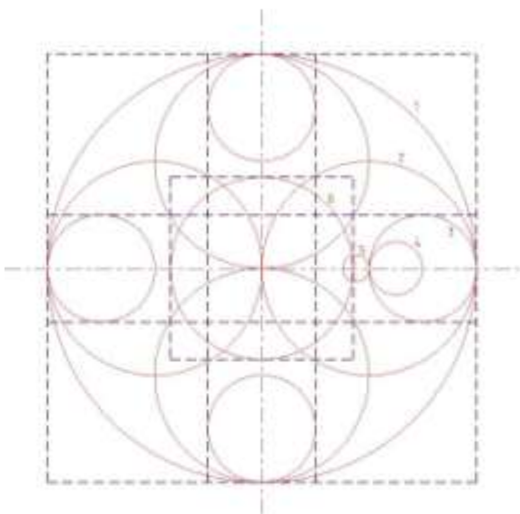

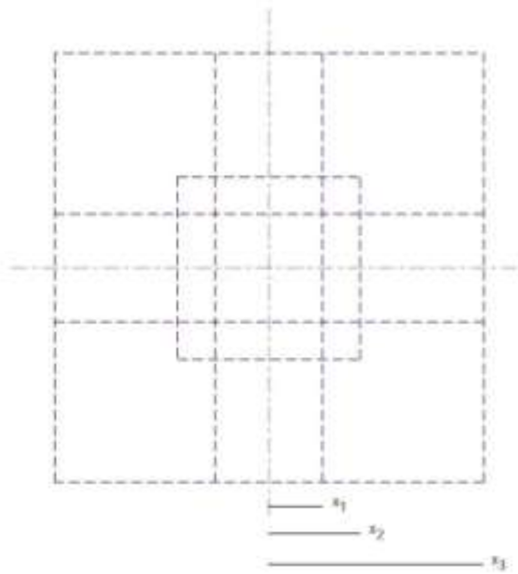

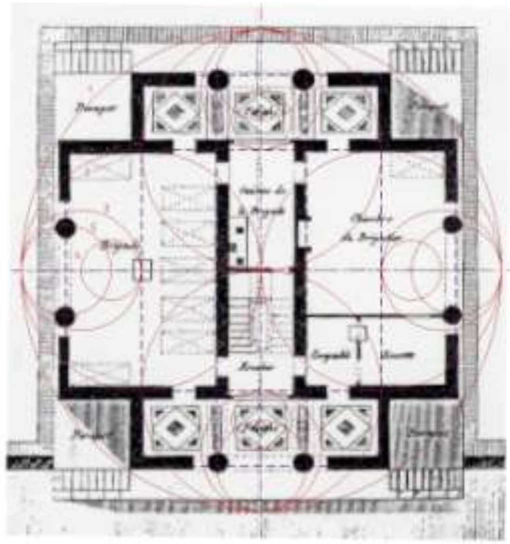

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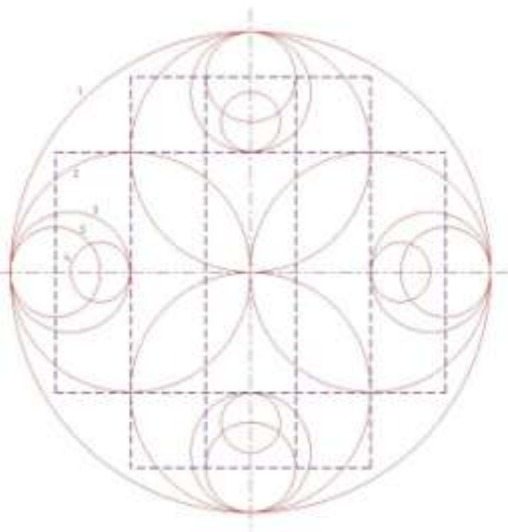

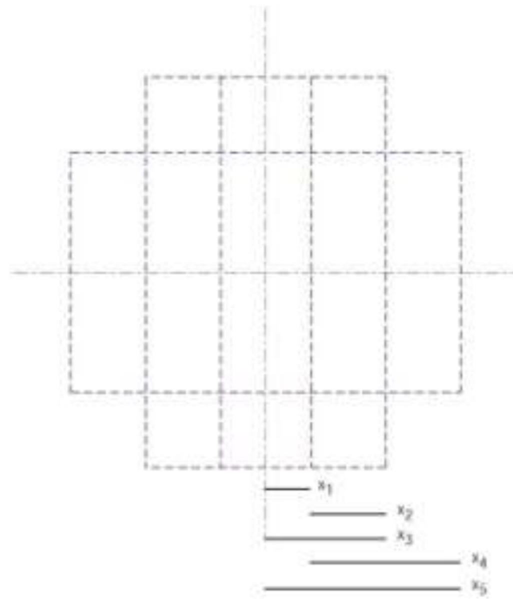

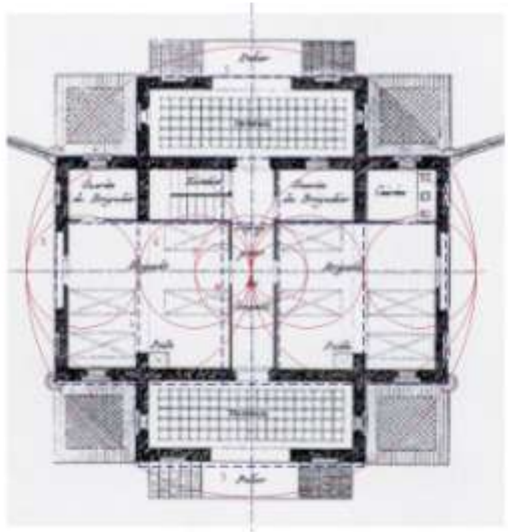

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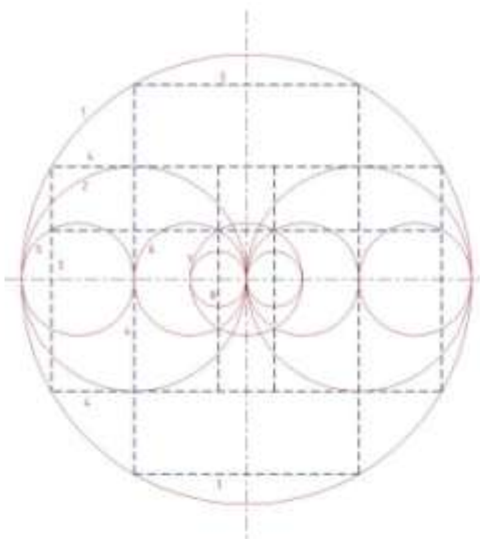

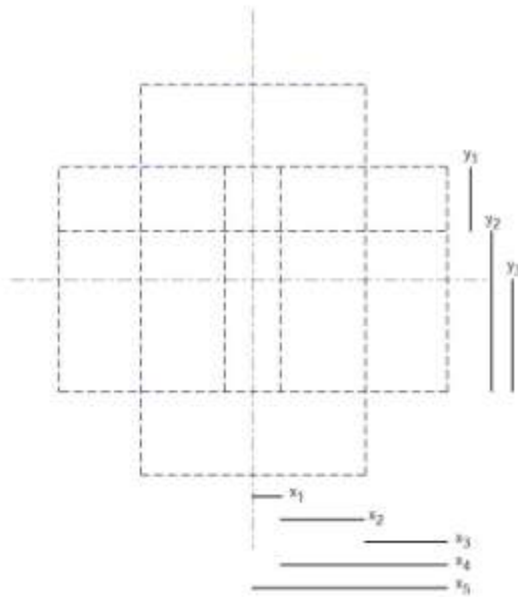

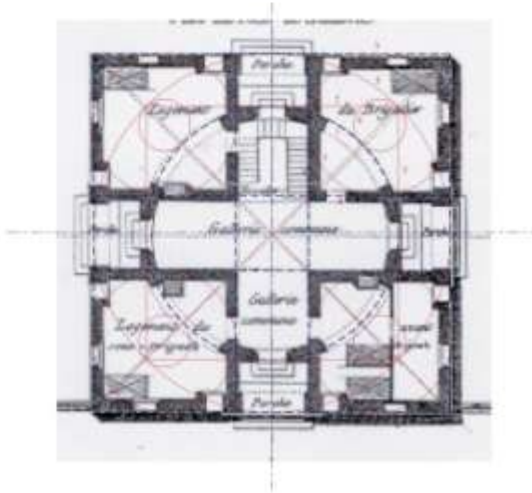

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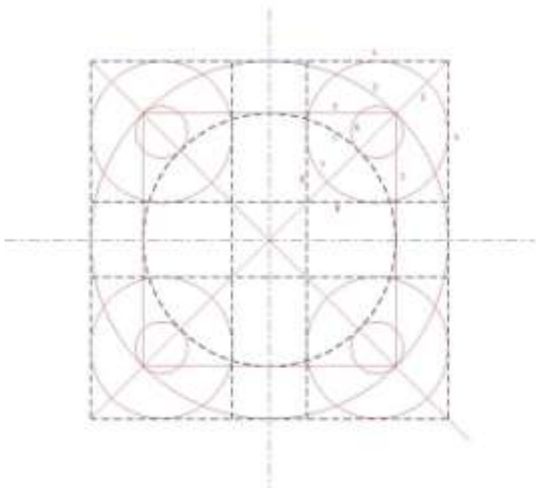

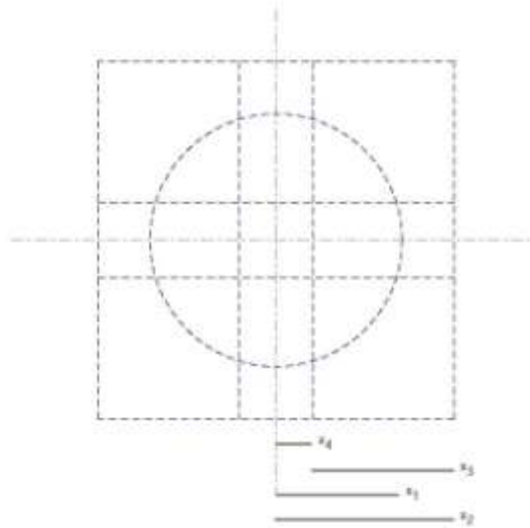

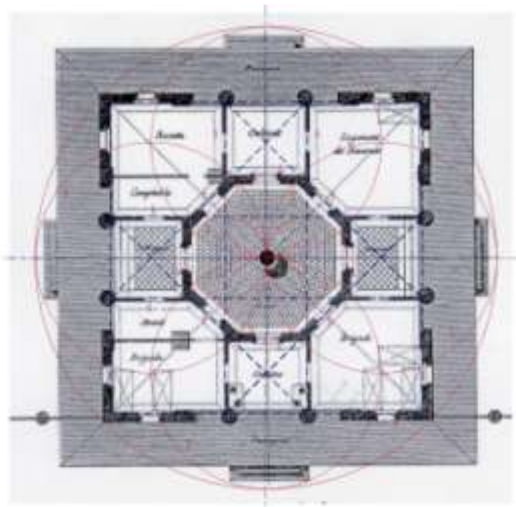

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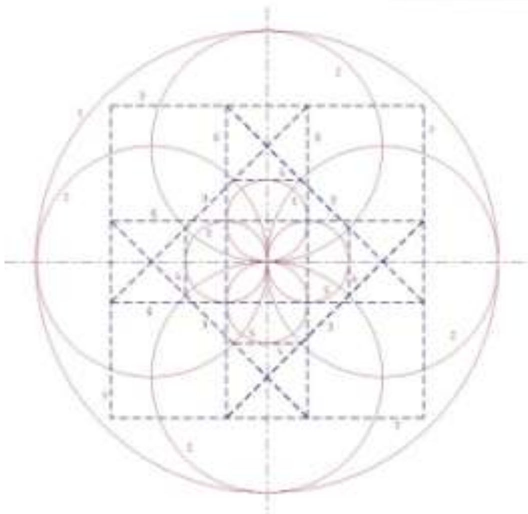

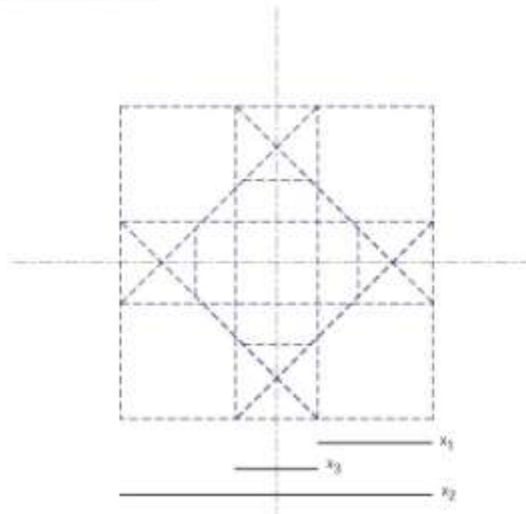

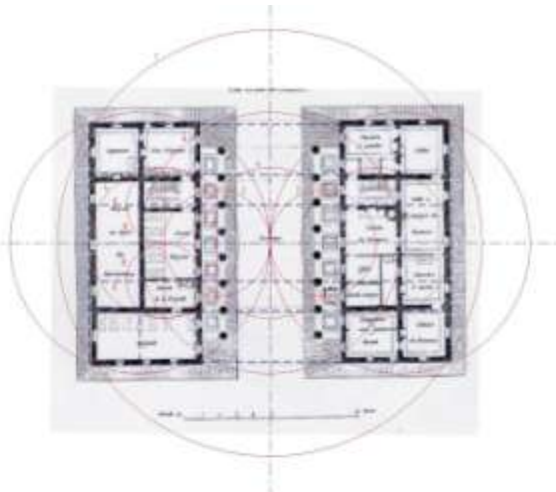

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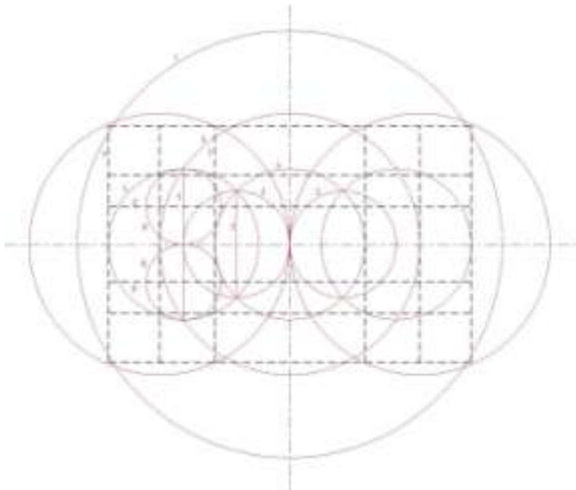

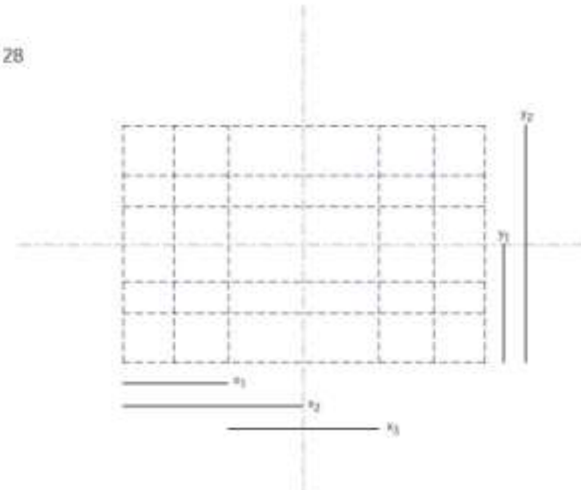

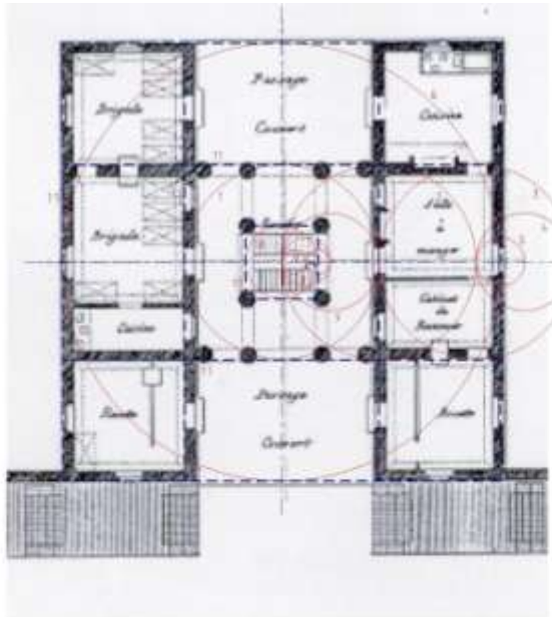

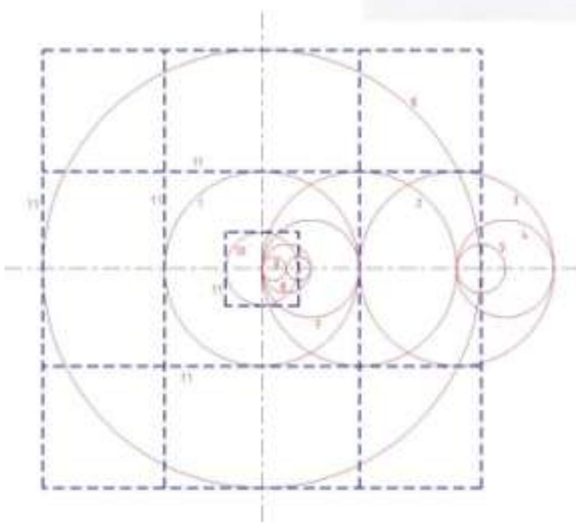

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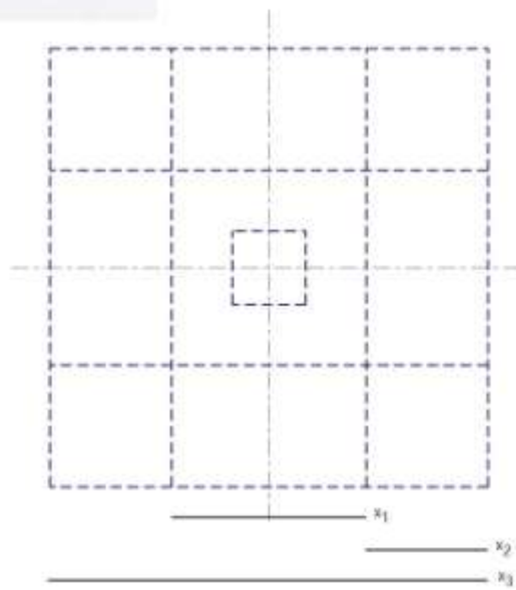

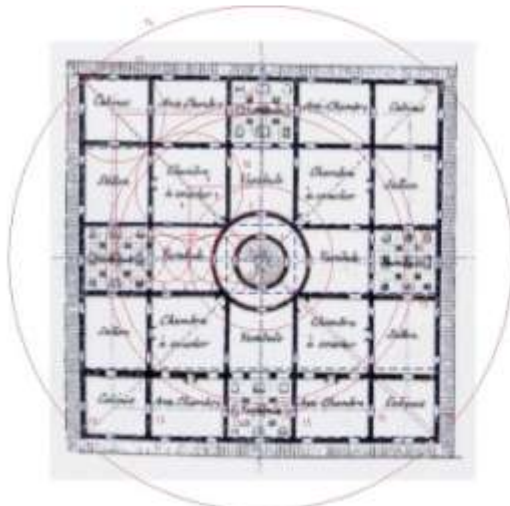

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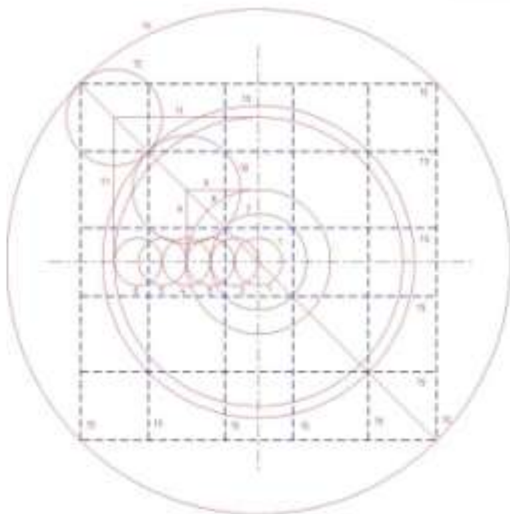

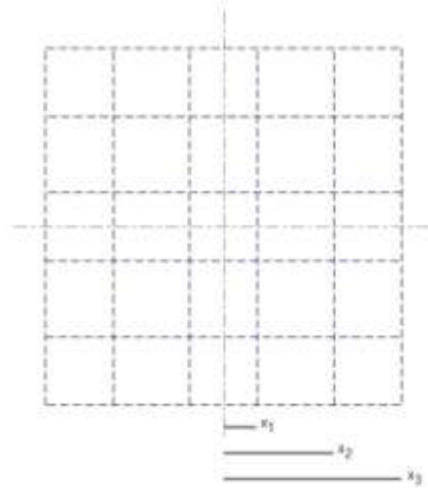

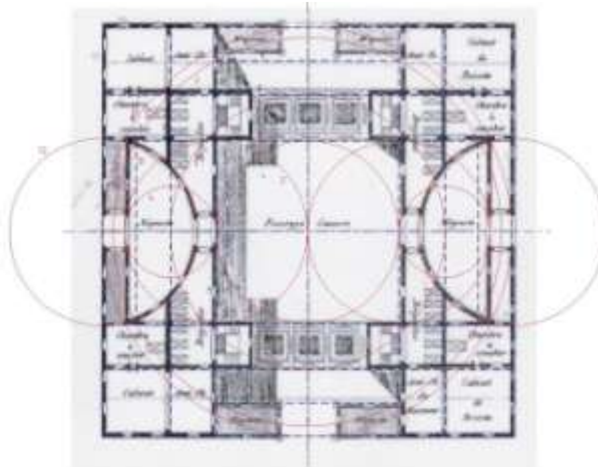

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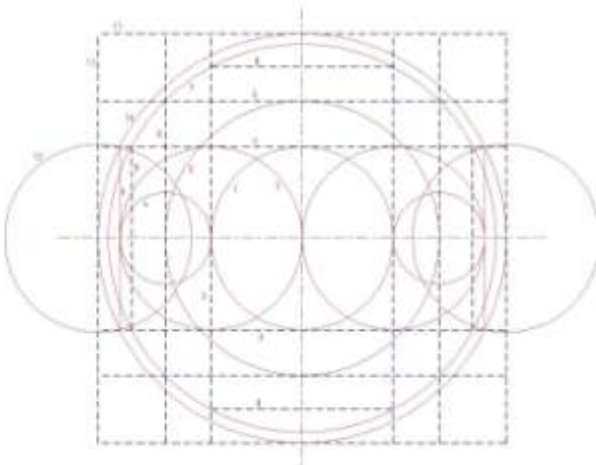

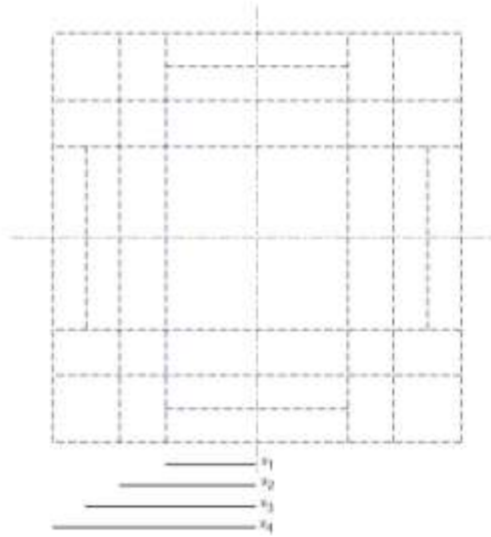

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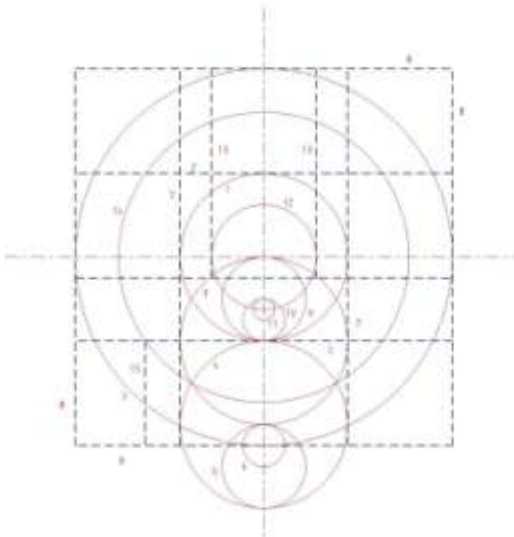

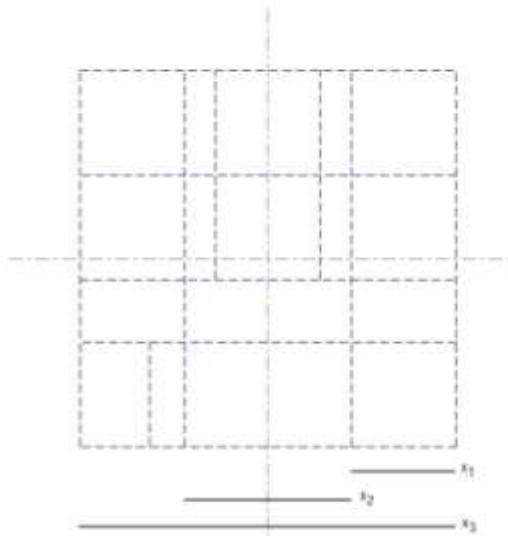

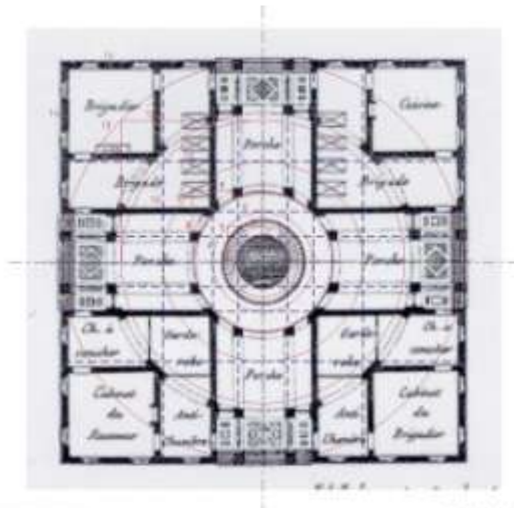

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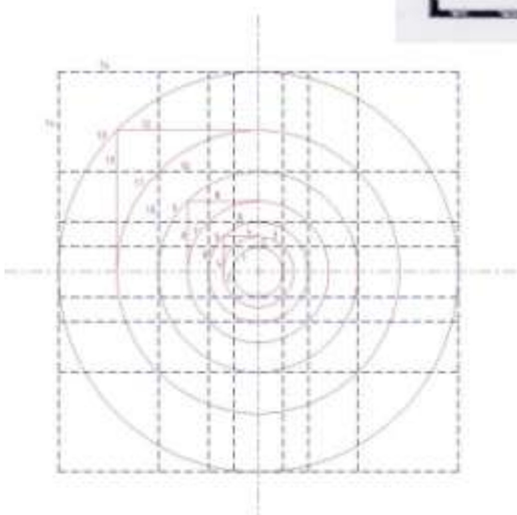

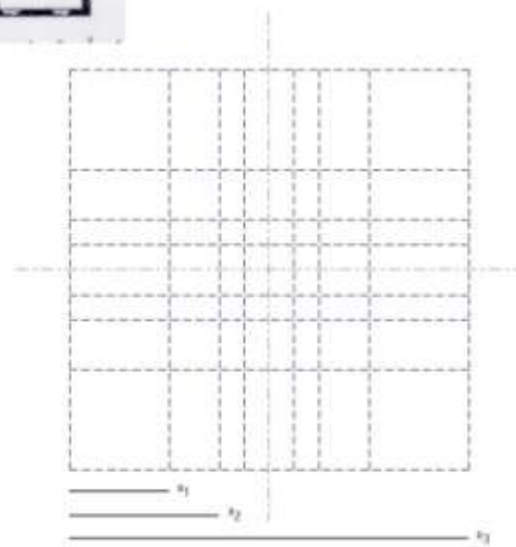

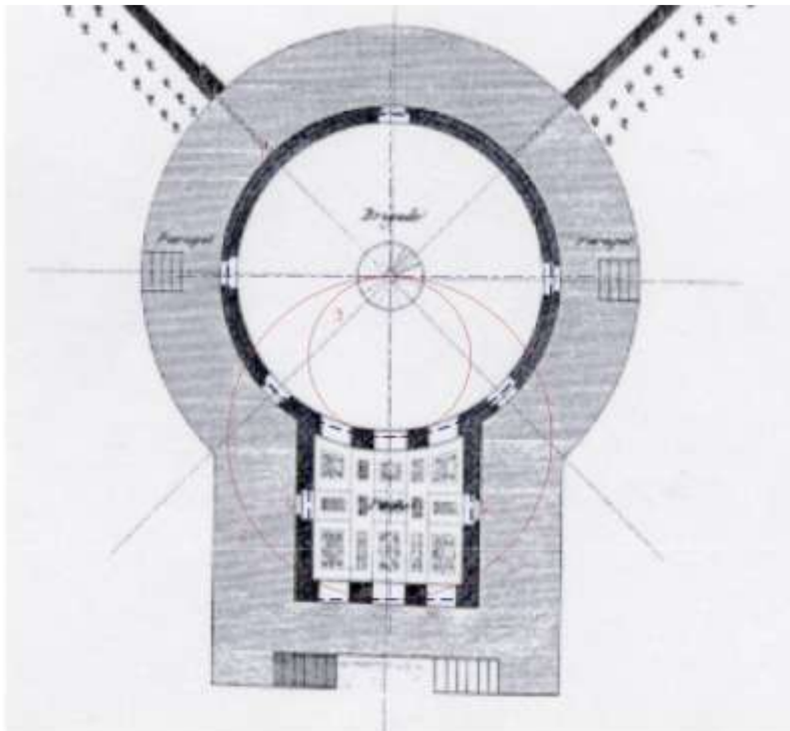

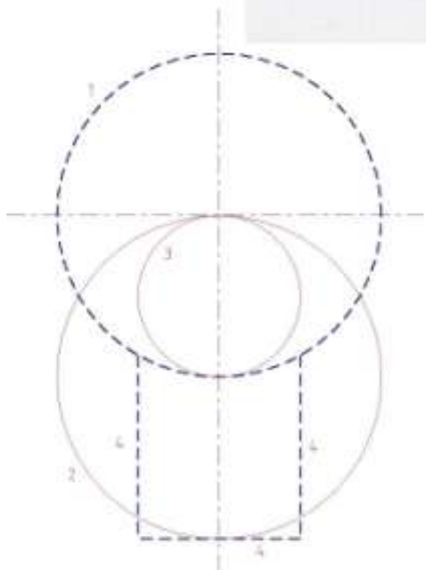

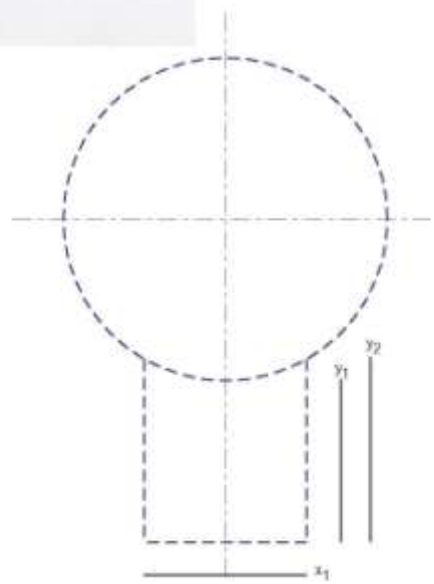

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