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RECOGNIZE THE INNER ENVIRONMENT ORGANIZATION WITHIN BUILDINGS OF ANCIENT CIVILISATIONS USING A QUANTITATIVE APPROACH (COURTYARD HOUSE CASE)

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ABSTRACT

The archaeological urban environment can be divided into an extern and an inner of buildings. The extern environment contains different infrastructures and superstructures, which can be identified through its urban typo-morphological logic. The inner environment of buildings, which via this paper focuses on, concentrating on spaces within buildings, means their organization, their order of functions, their spatial system, and their spaces genotype. This research aims to deduce the culture of ancient civilizations towards the way of organizing the inner functions and spaces within buildings. The first hypothesis said that each society has its own point of view, its own logic of ordering functions and topological relations between them. Each society has its own way of thinking toward the spatial structure within each type of buildings. The second hypothesis said that there are spatial organization similarities within the inner environment of buildings of ancient civilizations.

In affirming the hypotheses, the research adopts space syntax as a quantitative approach developed by the Laboratory of Space Syntax, UCL (University College London), which focuses on relationships between different spatial layouts and cultural and environmental phenomena. Space syntax approach goes beyond the descriptive aspect by using developed software such as Agraph. In this research, we followed the comparative methodology between four courtyard houses chosen from ancient civilizations, such as Mesopotamian, Greek, Roman, and Chinese

KEYWORDS: Environment, culture, space syntax, agraph, courtyard, environment, topologic, spatial, symmetry

1. INTRODUCTION

The house is a basic element of the urban human life, where its meanings were developed from many concepts such as the shelter, the dwelling, and the smart house. The courtyard house is one of the several forms and compositions that the house knew, which it was discovered in the ancient civilizations such as Greek and Roman (Abass et al., 2016). The courtyard is an enclosed space open to the sky (Edwards et al. 2006) to achieve many goals such as security and privacy (Al-Azzawi, 1994; Hawez Baiz & Jamal Fathulla, 2016), it is also a bounded space and a room without a roof (Ferrer, 2010), where based on cultural and environmental factors, the other rooms surround it (Mishra & Ramgopal, 2013; Abdelkader & Park, 2018). The courtyard happening in particular shapes and forms over climates and societies in numerous parts of the world (Rapoport, 2007), and it advertised an arrangement that balanced the natural limitations, the socio-cultural needs and the financial conditions tending to both fabric and immaterial needs of its inhabitants, depending to the local environment and to the social requirements (Al-Hussayen, 1995; Bougdah, 2017).

This paper aims to recognize the inner environment organization within typical courtyard houses of ancient civilizations using the space syntax tool, which is based on the analysis of the place structure, but it does not analyze the place character (Van Nes, 2014). The study of spatial configuration of the ancient civilization using this tool was the focus of various researchers such as: Benech, 2007; Stöger, 2011; Craane, 2013; Twaissi, 2017; Samantha, 2017; Palaiologou & Griffiths, 2019; Assassi & Mebarki 2021; Hamouda et al., 2021. "*Space syntax is a set of techniques for analyzing spatial configuration, and a set of theories linking space and society*" (Hillier, 2014). The Scale and integration are the properties of spatial configuration, where the spaces are represented by nodes, indicating the size and requirements of the spaces, and integration envelops the rings number and the communal spaces number (Malaque, 2018), as they are mentioned in the Fig. 1 (Dawson, 2002). Space syntax laboratory (University College London) developed using the intelligence and the speed of the software and the hardware various programs to analyze different urban and architectural spatial configurations, such as Depthmap and Agraph (Turner, 2001; Al-Sayed et al., 2014).

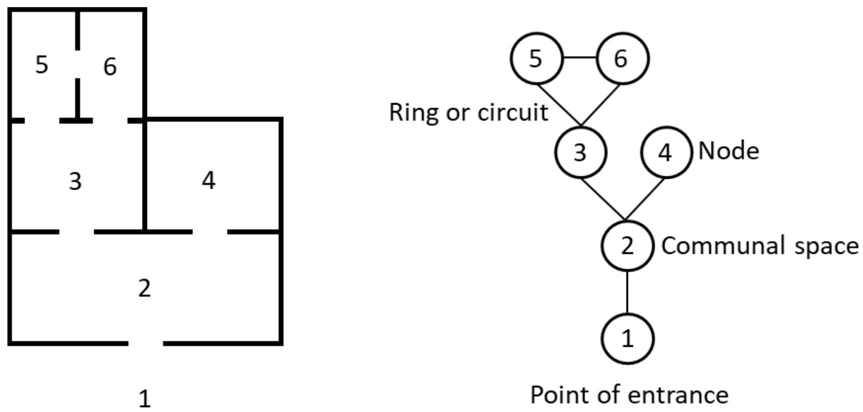

Figure 1. Properties of spatial configuration comprising scale and integration

2. METHOD AND MATERIALS

After making different layouts of the selected buildings, a specific graph called "Justified Graph" can be drown, as one of space syntax graphs showing different axial movement relations of a spatial system, which represents spaces as nodes and transitions from them as lines, as it is shown in figure 2 (Ostwald, 2011):

Fig. 3 (Hellier, 1996) shows the Justified Graph of a building where four topologic types of spaces are distinguished as follows (Al-Sayed et al., 2014).

- Topologic type of "a" space: It is the last space within a tree-like structure, which indicates that the movement is limited.
- Topologic type of "b" space: It is the transit space within a tree-like structure, which do not allow the user to move in the space freely.
- Topologic type of "c" space: It is the space with one annulus (annulus structure), which provides the user the choice of movement.
- Topologic type of "d" space: It is the space with more than one annulus (annulus structure), which allows the user to move in the space freely.

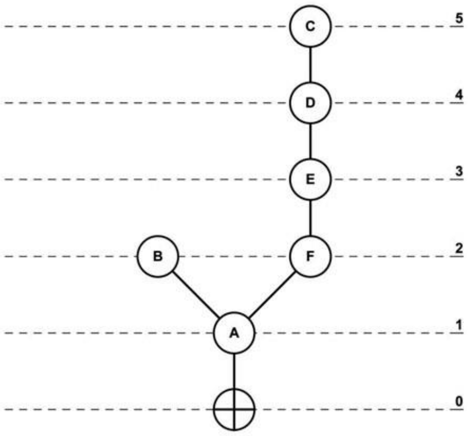

Figure 2. Example of a Justified Graph showing levels of transition starting from the exterior

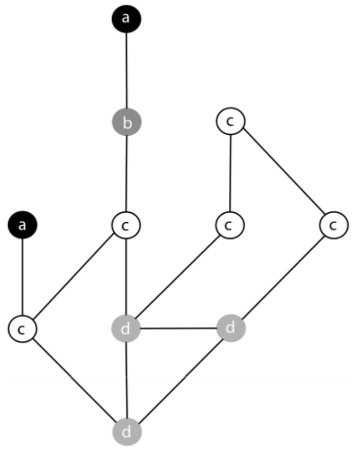

Figure 3. Justified Graph showing topologic types of spaces

Based on these topologic types of spaces, using mathematics formulas, spatial properties can be deduced, based on indicators of:

- The Distributivity or Non-Distributivity: Calculated to determine the existence or the absence of distribution, it equals:

Distributivity/Non-distributivity = (a + b) / (c + d)

- The Asymmetry or Symmetry: Calculated to know how much the spatial structure is integrated or isolated, it equals:

Asymmetry/Symmetry = (a + d) / (b + c)

If the resulting value is between 1 and 3, so the spatial structure is moderated, whether for distribution or for the symmetry. If the resulting value is less than 1, it means that the spatial structure is characterized by the distributivity, and the asymmetry, and if the resulting value is more than 3, it means that the spatial structure is characterized by the lack of the distributivity, and the symmetry.

Using Agraph program, starting from the exterior to the deep space (Fig. 2), serves to study quantitatively the relationships between spaces, where we can deduce other spatial properties, such as:

- The Integration Value: It is calculated to determine the proportion of integration in a system (the relative centrality of spaces).

Integration Value: i = 1/RA

Where:

RA is the Relative Asymmetry:

RA = 2 x (MD-1)/(K-2)

MDn is the Mean Depth (MD) for actual node: MD= TD/(K-1)

K is the number of nodes

TDn is the Total Depth (TD) for actual node: TD = (0 x nx) + (1x nx) + (2 x nx) +...(X x nx)

- The Difference factor: It represents a transit possibilities which allows to determine the type of fundamental social logic.

Difference factor: H = - (a/t x l_n(a/t) + b/t x l_n(b/t) + c/t x l_n(c/t))

Where:

a : Max RA, b : Mean RA, c : Min RA, t : a + b + c, and $l_n$is the natural logarithm of the base "e"

If the integration value is less than 1, it means that the spatial structure of the building is integrated. If the integration value is more than 1, it means that the spatial structure of the building is differentiated. If the difference factor value is close to 0, this indicates that the components of the building are distinct and different, and thus structured, and if the difference factor value is close to 1, it means that the constituent spaces of the building are homogeneous, and we do not find any structural differences between them.

3. COURTYARD HOUSES ANALYSIS

Mesopotamian typical courtyard house

The following is the spatial organization of a Mesopotamian typical courtyard house (Al-Dawoud, 2006, Fig. 4).

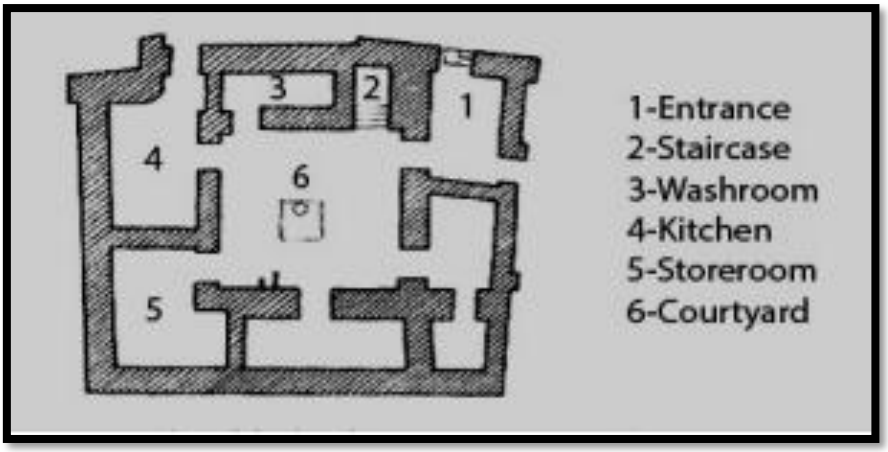

Figure 4. Layout of a Mesopotamian typical courtyard house

The following is the topologic types of spaces of this Mesopotamian typical courtyard house (Fig. 5):

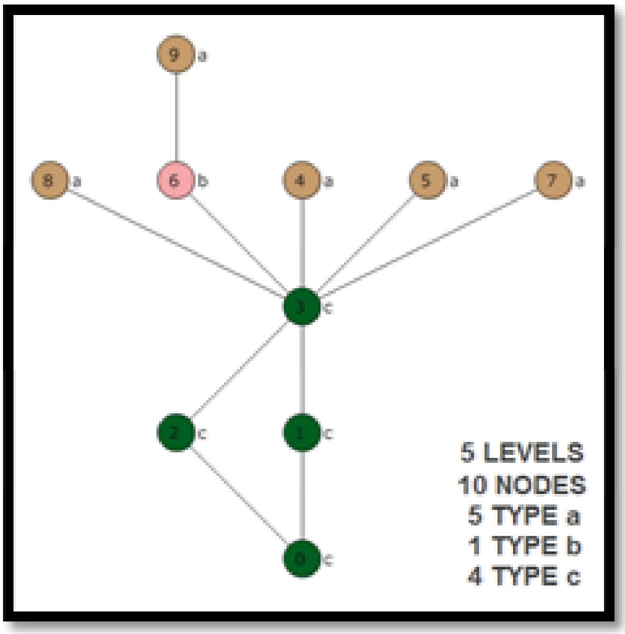

Figure 5. Justified Graph showing topologic types of spaces of the Mesopotamian typical courtyard house

This Mesopotamian typical courtyard house spatially is characterized by firstly, the in-between limited movement and providing choice of movement, where 50% of topologic types of "a" space, 40% of topologic types of "c" space, and 10% of topologic type of "b" space, with 0 topologic type of d space. Secondly, the moderated spatial system, whether for distribution or for the symmetry, where the result of the formula (a + b) / (c + d) distributivity equals 1.5, and the result of the calculated formula (a + d) / (b + c) equals 1. Thirdly, the differentiated spatial structure because the integration value is more than the arithmetic standard of 1, where it equals 5. Finally, the distinct spatial components because the Difference factor equals 0.

Roman typical courtyard house

The following is the spatial organization of a Roman typical courtyard house (Art History 342, Fig. 6).

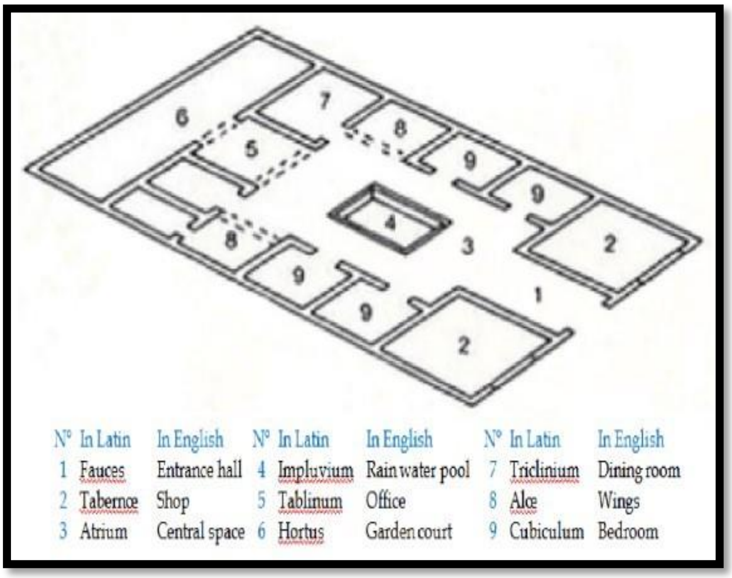

Figure 6. Layout of a Roman typical courtyard house

The following is the topologic types of spaces of this Roman typical courtyard house:

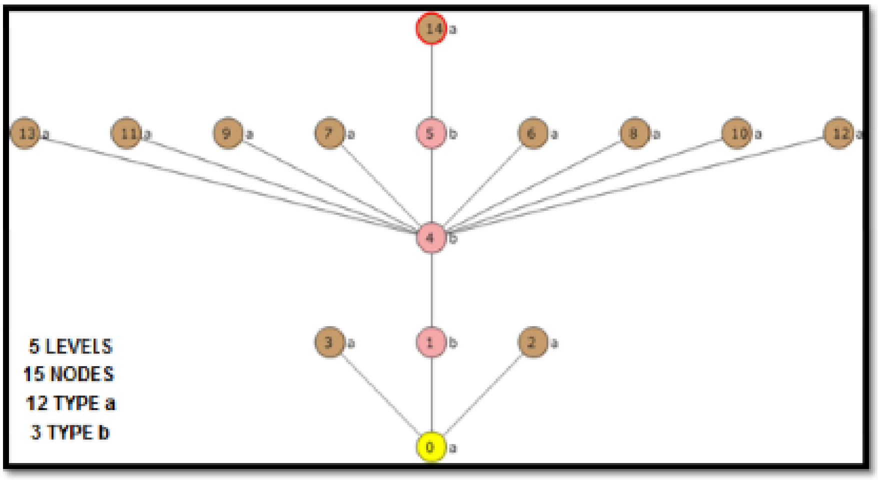

Figure 7. Justified Graph showing topologic types of spaces of the Roman typical courtyard house

The different spatial properties of this Roman typical courtyard house are firstly, the total limited movement and lack of distributivity, due to the absence of the topologic type of c and d spaces. Secondly, the symmetry because the result of the formula (a + d) / (b + c) is more than 3 as arithmetic standard, where it equals 4. Thirdly, the differentiated spatial structure because the integration value is more than the arithmetic standard of 1, where it equals 5. Finally, the distinct spatial components because the Difference factor equals 0.

Greek typical courtyard house

The following is the spatial organization of a Greek typical courtyard house (Book Units Teacher, 2000, Fig. 8).

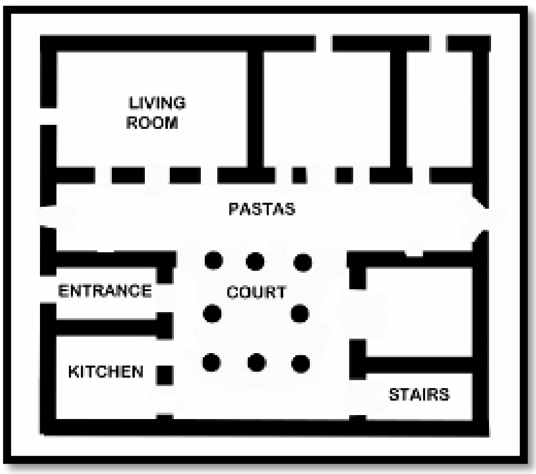

Figure 8. Layout of a Greek typical courtyard house

The following is the topologic types of spaces of this Greek typical courtyard house:

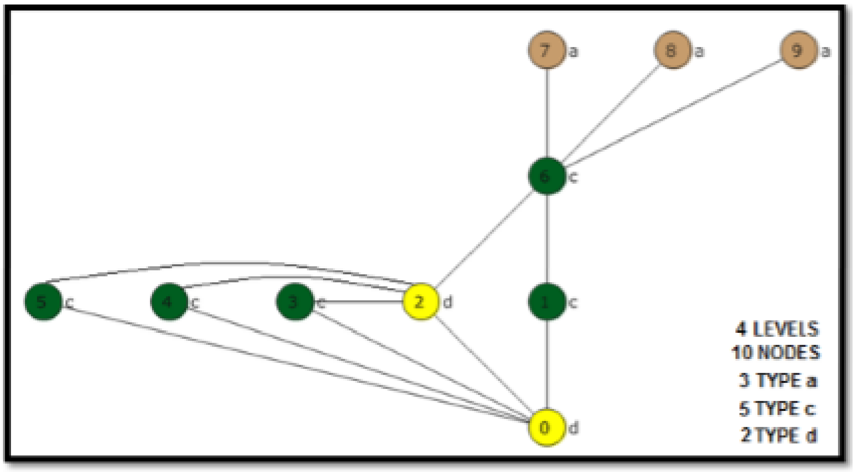

Figure 9. Justified Graph showing topologic types of spaces of the Greek typical courtyard house

The spatial properties of the analysis results of this Greek typical house are firstly, the free choice of movement at a rate of 60%, with 0 topologic type of space, and from 10 nodes there are only 3 topologic types of a space. Secondly, the distributivity, due to the result of the formula (a + b) / (c + d) which is less than the arithmetic standard of 1, and which equals 0.428. Thirdly, the in-between symmetry and Asymmetry because the result of the formula (a + d) / (b + c) equals 1, which means that is between the two arithmetic standards of 1 and 3. Fourthly, the differentiated spatial structure because the integration value equals 5.194, which means that is more than the arithmetic standard of 1. Finally, the distinct spatial components due to the Difference factor which equals 0.

Chinese typical courtyard house

The following is the spatial organization of a Chinese typical courtyard house (Zhang, 2015, Fig. 10).

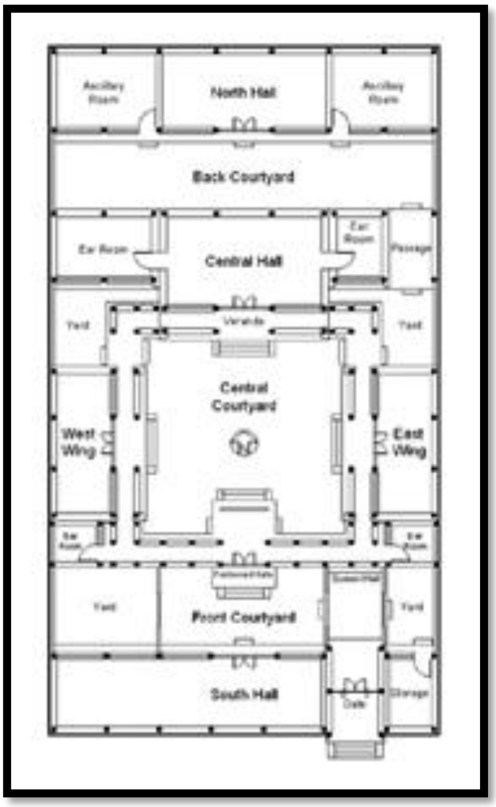

Figure 10. Layout of a Chinese typical courtyard house

The following is the topologic types of spaces of this Chinese typical courtyard house:

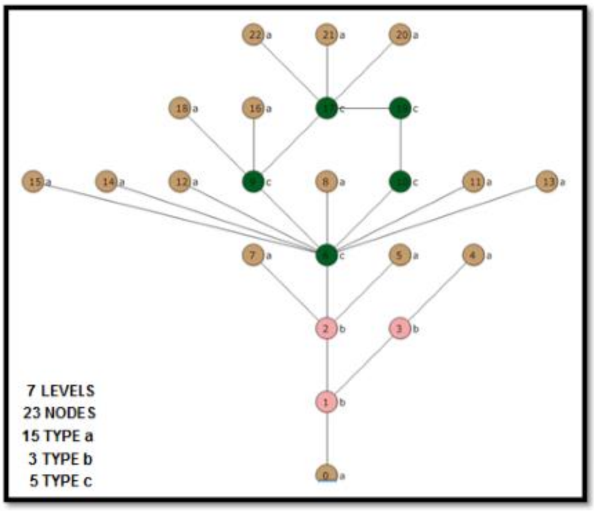

Figure 11. Justified Graph showing topologic types of spaces of the Chinese typical courtyard house

The spatial analysis of this Chinese typical house leads to firstly, the free choice of movement at a rate of 60%, with 0 topologic type of d space, and only 7 topologic types of c space from 23 nodes. Secondly, the lack of distributivity because the result of the formula (a + b) / (c + d) equals 3.60, which means that is more than the arithmetic standard of 3. Thirdly, the in-between symmetry and Asymmetry because the result of the formula (a + d) / (b + c) is between the two arithmetic standards of 1 and 3 where it equals 1.87. Fourthly, the differentiated spatial structure because the integration value is more than the arithmetic standard of 1 where it equals 5. Finally, the distinct spatial components where the Difference factor equals 0.

Comparison

The following table contains numerical information of the justified graphs of the analyzed houses:

Table 1. Numerical information of the justified graphs of the analyzed houses

Houses	Levels of transition	Number of nodes	Topologic types of spaces			
			"a"	"b"	"c"	"d"
Mesopotamian house	5	10	5	1	4	0
Roman house	5	15	12	3	0	0
Greek house	4	10	3	0	5	2
Chinese house	7	23	15	3	7	0

According to the table 1, starting from the exterior, the Mesopotamian house contains five levels of transition like the Roman house with ten nodes like the Greek house, but with five topologic type a spaces, four topologic type c spaces, one topologic type b space, and like the Roman house and the Chinese house, no topologic type d space. The Roman house like the Mesopotamian house, it contains five levels of transition but with fifteen nodes, where twelve topologic type a spaces, three topologic type b spaces, and we note the absence of the topologic type c space unlike the other houses, and the inexistence of the topologic type d space like the Mesopotamian house and the Chinese house. The Greek house, unlike the other houses, it contains only four levels of transition, and it contains ten nodes, but with only three topologic type a spaces, and unlike the other houses, no topologic type b space, five topologic type c spaces, and two topologic type d spaces. The Chinese house contains seven levels of transition unlike the other houses, with twenty three nodes also unlike the other houses, in which fifteen topologic type a spaces, three topologic type b spaces, seven topologic type c spaces, and no topologic type d space.

According to the table 1, starting from the exterior, the Chinese house contains the biggest number of the levels of transition, and the Greek house contains the least number of the levels of transition, and the Chinese house contains the biggest number of the nodes, while the Mesopotamian and the Greek house contain the least number of the nodes. The research affirms the absence of the topologic type a space in the Mesopotamian house, the topologic type c and d space in the Roman house, the topologic type b space in the Greek house, and the topologic type d space in the Chinese house.

The following figure 12 is the bars chart of Distributivity/Non-distributivity and Asymmetry-Symmetry indicators of the analyzed houses.

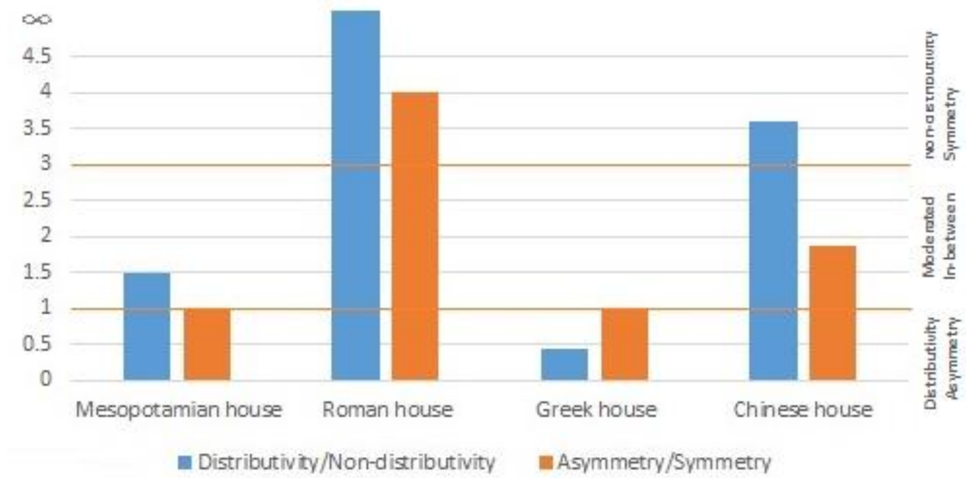

Figure 12. Bar chart of Distributivity/Non-distributivity and Asymmetry-Symmetry indicators of the analyzed houses

The following Fig. 13 is the bars chart of Integration value and Difference factor indicators of the analyzed houses:

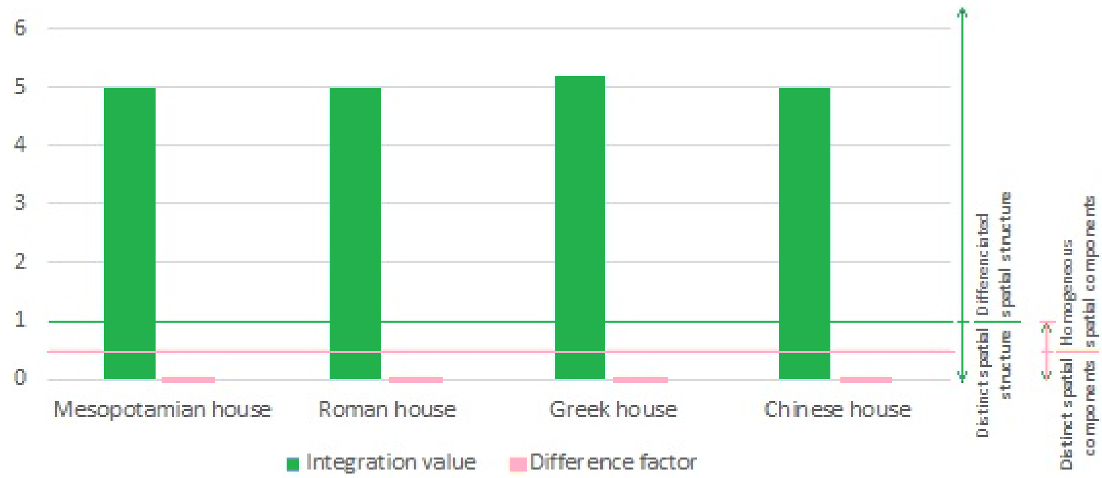

Figure 13. Bars chart of Integration value and Difference factor indicators of the analyzed houses

The following Table 2 contains spatial properties of the analyzed houses, where we used colors to indicate similarities and differences between them:

Table 2. Spatial properties of the analyzed houses

Houses	Distributivity/ Non-distributivity	Asymmetry/ Symmetry	Integration value	Difference factor
Mesopotamian house	Moderated	In-between symmetry and asymmetry	Differentiated spatial structure	Distinct spatial components
Roman house	Lack of distributivity	Symmetry	Differentiated spatial structure	Distinct spatial components
Greek House	Distributivity	In-between symmetry and asymmetry	Differentiated spatial structure	Distinct spatial components
Chinese house	Lack of distributivity	In-between symmetry and asymmetry	Differentiated spatial structure	Distinct spatial components

Regarding Fig. 12, Fig. 13, and Table 2, the research notes firstly, for the Mesopotamian house, that its spatial system is moderated between the distributivity and the non-distributivity, which means that is different than the other houses, while its spatial system is moderated between the symmetry and the asymmetry like the other houses, and the integration value indicates that it holds a differentiated spatial structure like the other houses, and also the difference factor indicates that it has distinct spatial components like the other houses. Secondly, the Roman house lacks of distributivity like the Chinese houses, while it is characterized by the symmetry unlike the other houses, and regarding the integration value and the difference factor, this house is similar than the other houses, which means it has a differentiated spatial structure and distinct spatial components. Thirdly, the Greek house is characterized by the distributivity unlike the other houses, while its spatial system is moderated between the symmetry and the asymmetry like the other houses, and it has a differentiated spatial structure and distinct spatial components like the other houses. Finally, the Chinese house is characterized by the lack of the distributivity like the Roman house, and like the other houses, its spatial system is moderated between the symmetry and the asymmetry, and also like the other houses, it holds a differentiated spatial structure and distinct spatial components.

4. CONCLUSION

The spatial analysis of each typical house and then the comparison between them leads to say that firstly, for the levels of transition, which, among its meanings it indicates the deepness and socially privacy or shallowness and socially openness, showed that the Greek house is closer to openness than the other houses, while the Chinese house is more deep and then holds the characteristic of privacy, but the Mesopotamian and the Roman house are moderated houses in terms of privacy and openness. Secondly, for the number of nodes, which is based on functions division and socially means the segmentation of the activities. The Chinese house is more segmented in terms of functions and activities than the other houses, where the biggest number of functions is located in the fourth level, and like this house the Roman house appears segmented, but it is least in terms of number of functions, where also the big number of functions is located in the fourth level, while the Mesopotamian house and the Greek house group the activities, where the functions appear fewer than the previous houses, but also the big number of functions are located in the fourth level in the Mesopotamian house, and the big number of functions are located in the second level in the Greek house, which confirms the openness of this last house. Thirdly, for the topologic types of spaces, based on spatial system logic, showed that the Roman house has only two topological types a and b spaces, then this means that its spatial structure is characterized by the limitation of movement and the integration of the atrium as the center of the social way of life within this typical house, while the Greek house as within it the number of topological types c and d spaces is greater, then this means that the spatial structure is characterized by the flexibility and openness of movement and decentralization of functions, and as the Mesopotamian house and the Chinese house contain the topological types a, b, and d spaces without the existence of the topologic types d space, they seem to be moderated in terms of openness of the inner social life to the exterior. Fourthly, the Distributivity/Non-distributivity indicator showed that the Greek house appears with many entries from the exterior without an always obligation to pass via the courtyard, and vice versa for the rest of the houses, but for the Asymmetry/Symmetry indicator, despite that the Roman house is segmented in terms of functions, it is characterized by the symmetry in terms of spaces, while all other houses are in-between Asymmetry and Symmetry. Finally, the indicators of Integration Value and Difference Factor showed that in addition to the similarities and to the differences between houses mentioned above, there are other similarities such as differentiating the spatial structure and then the activities within houses and distancing the spatial components, but each house with its appropriate way of mapping its own social life within it.

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