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SPATIAL CONFIGURATION ANALYSIS VIA DIGITAL TOOLS OF THE ARCHEOLOGICAL ROMAN TOWN TIMGAD, ALGERIA

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ABSTRACT

In this research project, we studied the ancient Timgad site which has been classified on the World Heritage List of Humanity by UNESCO, in order to understand quantitatively and digitally what was its urban and architectural spatial configuration as no earlier studies were made about this archeological site. The approach to this important question was the space syntax method via its digital tools applications, such as Depthmap and Agraph. Using these software programs and quantitative metrics, it was possible to identify elements that lead us to distinguish between the spatial properties within the urban site related to access, flow, individual behaviour, and the amenities inside of an average building, with considerations which are related to accessibility, movement, and way of life. These findings lead us to assess the spatial archeological value. Valuable elements to the architects, urbanists, and archaeologists are related to the understanding of the social domestic life found through the excavated archeological buildings within the framework of human anthropology.

KEYWORDS: Archaeological Town Planning, Roman Town, Digital Tools, Timgad, Space Syntax, Depthmap, Agraph.

1. INTRODUCTION

The concept of a "town" develops through time and extends from place to place and from local history to general history; however, it remains the principle of civilisation and development. The Roman civilisation is important in human history; it had a big impact on many places in the world, like Algeria, where it constructed important towns such as Timgad. Timgad is characterized by monumental and orthogonal town planning. This has attracted many researchers of various disciplines to the town to do deep studies via various approaches and tools such as Masqueray, 1876; Moliner, 1891; Ballu, 1910; Courtois, 1951; Lassus, 1969; Le Bohec, 1996; as ancient references, and Bouchareb, 2009; Chergui, 2011; Matmar, 2011; Bahloul Guerbabi, 2016; Bouzeghaia and Maachi, 2016; Saidia 2017; Tamarhoult, 2020, as recent references. In this study, as we focus on the spatial configuration of this town, we adopt the approach of space syntax. Providing a set of theories and a method, this approach concentrates on the relationship between lines based on movement patterns within space (Hillier and Hanson, 1984). In the space syntax approach, the navigation of space is intrinsic to human activity and its spatial configuration. The method addresses four components that are used in all space syntax analyses: representations of spaces, analysis of spatial relations, interpretive models, and theories. Using space syntax method we can analyse the invisible in ancient domestic spaces (Giles, 2009, Sahin et al., 2021), understand the configurational thinking in ancient civilisations, (Letesson, 2010), and understand also the ancient cities and their social life by the numbers (Stöger, 2015). Based on this approach and its tools, we aim to deduce the spatial properties and characteristics of the archaeological Roman town of Timgad.

The novelty in this research is that in the archaeological urban and architectural setting of Timgad, we infer invisible spatial notions via numerical measures which have not been addressed in any study previously. So, the importance in theoretical and practical ground of this work appears where we exceed the qualitative analysis by the quantitative analysis and where we exceed the description by the quantum precision.

The objective of our study is not to understand the urban nor architectural historical development of the archaeological site of Timgad, the objective of our study is to understand computationally how does any user of the urban space of the archaeological site of Timgad behave (what and how does he view and how does he move ?). In addition to that, we aim to affirm that space syntax approach conducts as to understand quantitatively the domestic space of a typical Roman house which prompts us in the next future article to carry out architectural surveys of archaeological buildings of Timgad to study their spatial structure by computer according to the comparative methodology.

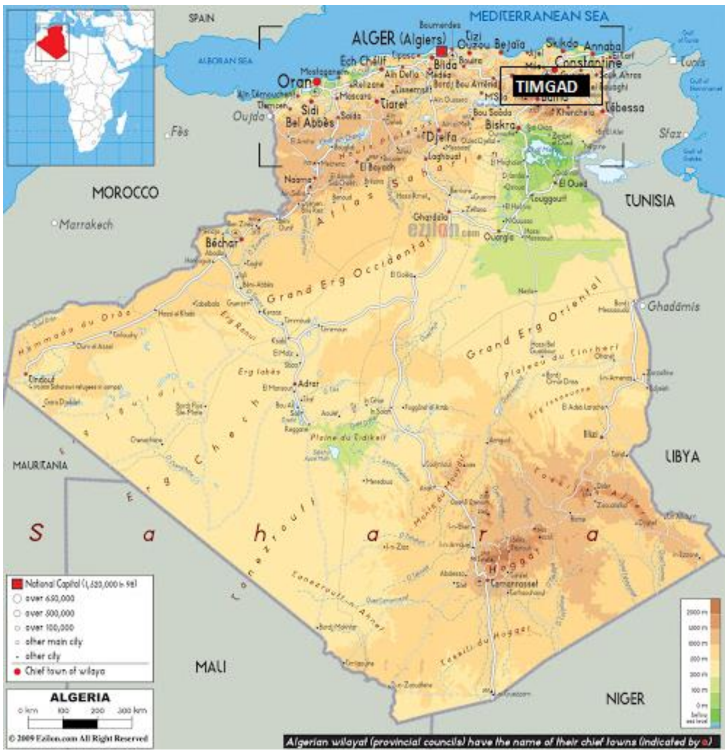


Figure 1. ***Geographic location of Timgad***
Source: http://www.vidiani.com/large-physical-and-road-map-of-algeria/

2. CASE STUDY

Fig.1 shows that Timgad is located in a mountainous site of great beauty that is north of the Auras massif, 480 km south-east of Algiers, and 110 km south of Constantine. As it is positioned between 950 and 1000 m above sea level, its climate is of the high plateaus, which is dry and hot in the summer and cold in the winter.

About the creation of Timgad, according to the website of UNESCO (2020): *"Timgad lies on the northern slopes of the Aurès mountains and was created* ex nihilo *as a military colony by the Emperor Trajan in AD 100."* (https://whc.unesco.org/en/list/194/). Fig.2 shows the west gate, called arch of Trajan. After the Roman Empire, the city was occupied by the Vandals, the Byzantines, and then, the Arabs.

To avoid confusion related to the purpose of the article in which the reader may fall, our study concerns with space syntax analysis not other approach, and since there are conflicting opinions about the history of Timgad, and as we do not focus in our article on historic method nor historic development, we above mentioned only some historic information for only introducing the case study, and we mentioned some ancient and recent references for readers who want to expand on Timgad history.

About the original shape of Timgad, according to the website of UNESCO (2020): *"With its square enclosure and orthogonal design based on the* cardo *and* decumanus, *the two perpendicular routes running through the city, it is an excellent example of Roman town planning."* (https://whc.unesco.org/en/list/194/). Fig.3 shows that the original town of Timgad was characterized by the square enclosure and orthogonal design, with two intersecting main streets crossed it: Cardo maximus and Decumanus maximus. We mention here that it is wrong if we say that the direction of cardo maximus is absolutly running from north to south because the cardo maximus does not apply 100% to the north direction line, it is slightly tilted with 5° to the west (Bouchareb, 2009). And it is wrong if we say that the direction of decumanus maximus is absolutely running 100% from east to west, because the decumanus maximus is slightly tilted to the south.

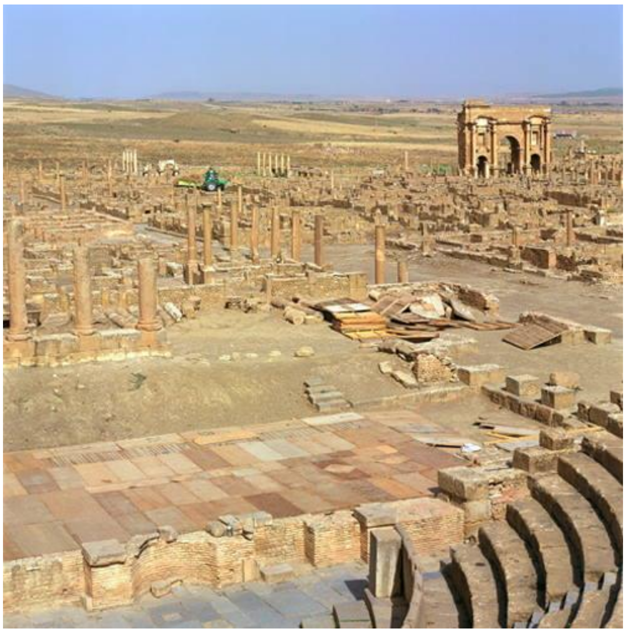


Figure 2. Photo from inside the ancient town of Timgad
Source: https://whc.unesco.org/fr/list/194/

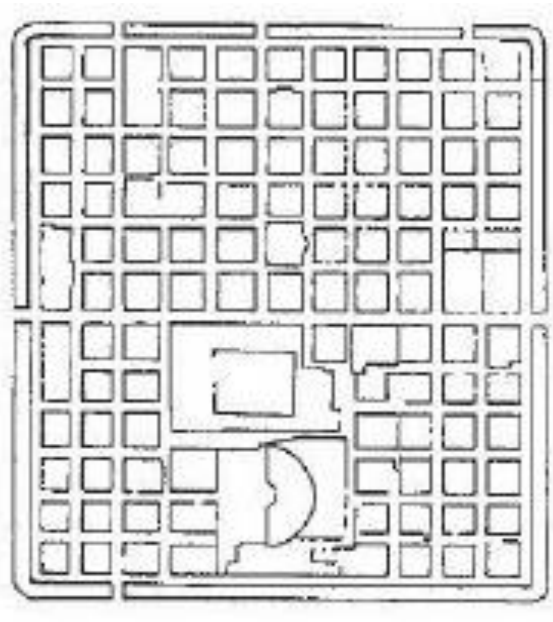


Figure 3. Trajan colony planning (Original boundary)
Source: Thebert, 2003

Timgad has known many fossils until it was classified by UNESCO in 1982 on the World Heritage List of Humanity (Fig.4, shows one of the plans which indicates the delimitation of the non-aedificandi zone of monumental Timgad).

Excavation researches on the urban composition of the ancient town of Timgad discovered that Timgad expanded so that it came out of the original boundary, and it did not maintain its orthogonal shape, as shown in Fig.5 (We mention here that the original version of the plan represented in this figure was elaborated by the land surveyor expert Chergui (2011), which is cited in the website of the UNESCO, and we also returned to the plan of Courtois (1951), and the plan of Lassus (1969). During the months of August and 2020, we tried our best to correct and to update it as we can, and it became as shown in this figure by dark-red color).

Regarding title of our paper, the limitation of our study is related to the Roman period that is why we do not study the Byzantine period. Then, to avoid overlap in periods, and since our goal is to understand the user visual and movement behavior within the resulting urban structure of Timgad archaeological site, we selected two zones, which have different geometric and topologic urban shapes: ZONE 1 (Limited by the original boundary, which is characterized by its orthogonal shape), and ZONE 2 (Part of the expansion out of the original boundary, which is characterized by its non-orthogonal shape, and which contains important buildings such as capitol, industrial district, basilica, large south baths, temple of the genius of the colony, market of Sertius, and market baths of Sertius.). We point out here that it is possible to expand the study in the future papers on all the ancient city of Timgad, after completing all the urban and architectural surveys.

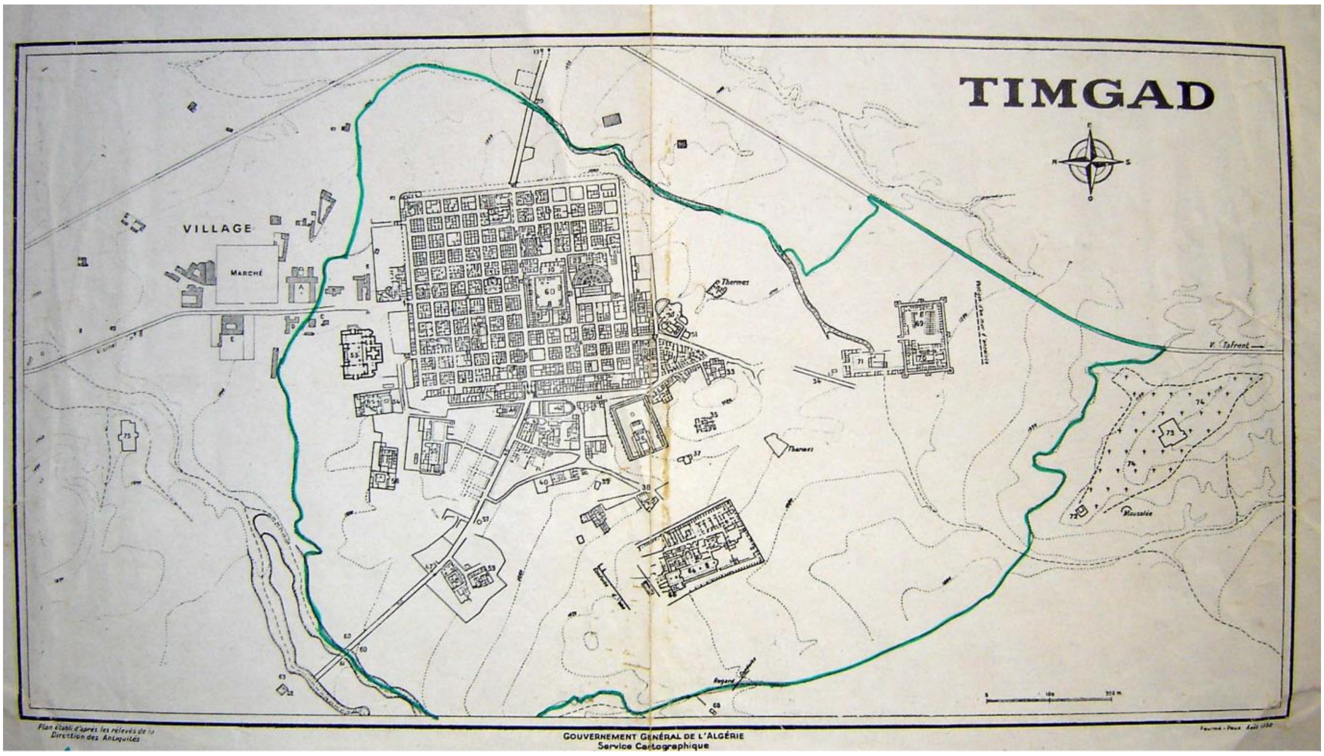


Figure 4. ***Limit of the non-aedificandi zone of monumental Timgad during the French colonial period***
Source: https://whc.unesco.org/fr/list/194/multiple=1&unique_number=215

3. APPROACH AND METHOD

Many archaeological research projects have been successfully conducted based on the space syntax approach, such as the research of Twaissi (2017). Other examples include the study of the morphological characteristics of Anatolian fortified towns (Kubat, 1997), medieval towns (Craane, 2009), the Hellenistic and Roman site of Dura-Europos in Syria (Benech, 2007), the level of street vitality in the Roman town of Pompeii (Van Nes, 2009), the urban society of Rome's imperial port-town of Rethinking Ostia (Stöger, 2011), streets and the organization of space in Roman cities (Kaiser, 2011), and the spatial patterns of late medieval and early-*modern* towns (Craane, 2013).

Within urban space, human movement is mainly related to the choice of a destination; this is measured by (1) *integration*, which means ease of access, and (2) *passing flow*, which refers to the selection of a route. The configuration of various spatial elements is the result of the different relationships between those two considerations. Streets, boulevards, alleys, and so on are components of the *spatial street network*, which can be represented by *axial* and *segment maps* in terms of axial lines and segments (EPUM, 2020). Segment maps help to represent the semi-continuous lines in the street system, "*This representation is on the level of street segments, considering their topological, metric and angular connections*" (Al_Sayed et al., 2014). The movement patterns of people can be done through *isovist field analysis* (Benedikt, 1979) which means the area in a spatial environment directly visible from a point, "*to provide a measure of how well integrated isovists themselves are within a plan of an environment*" (Turner and Penn, 1999). Isovists, agents, with axial lines, are the ingredients of an exosomatic cognitive map (Turner, 2007). We used *visibility graph analysis* to convey visual information to observers of buildings by inhabitants and visitors (Abshirini and Koch, 2013, p. 1). According to Turner (2004), "*The methodology was later formalized more simply as visibility graph analysis (VGA) (Turner et al., 2001)*" (Turner, 2004, p. 1). Using the visibility graph, we can make different global and local measurements such as that of *point depth entropy*, which allows us to explore the measurements of the distribution depths frequency, and the *clustering coefficient*, which gives a measure of the intra-visibility of points, and so on. Also, Alasdair Turner developed the method of *agent analysis* to examine human pedestrian behaviour in the built environment by considering how pedestrians adapt to changes in space (Turner and Penn, 2002). This type of analysis can be done through the use of a 2D view window in order to consider agents' movement in space, or it can be done using a 3D visualisation to represent agents in action (Al_Sayed et al., 2014). Using agent analysis for example, space syntax also can be related to hierarchical and prediction modeling where we can predict the movement possibilities of destinations and choice (Itzhak and Nir, 2017).

Inside buildings, if a straight line is drawn between any two spaces outside one of its constituent subspaces, we can divide those subspaces into convex spaces and examine them using a convex map (Assassi, 2017). In other words, the convex map is related to adjacency relationships where we divide concave spaces into convex spaces in order to avoid having to consider broken or refracted lines. In the analysis, all pairs of lines are inter-visible with a minimum of one step of depth if there is no space separating them, and two steps of depth if there is one space separating them, and so on. Each space is identified by a node (vertex) and related by one line or more, where the hole is represented within a justified graph. The movement rings that the graph depicts reflect the spatial topology of the type of space being considered, such as dead-end spaces, and so on. The justified graph leads to different measures, such as connectivity and integration in order to explain social and domestic behaviour (Al_Sayed et al., 2014). We also stress an important point, that the mathematics of the spatial configuration was mentioned in many researches as one of the bases of space syntax theory (such as Hillier, 1995; Turner et al., 2001; Ostwald, 2011).

In our case, as the urban morphology begins to appear more orthogonal, we first analysed the axial map of the ancient town of Timgad in order to determine the level of both movement-to and through-movement in the town. Then, we analysed the urban visibility graph to determine the visual information and level of urban perception within the town. After that, we moved on to considering the results of an agent analysis to understand how individuals/agents behave within urban spaces. Finally, we used the convex map of architectural spaces to analyse a typical Roman atrium house sample in order to understand the domestic way of life in this sample of house.

To achieve these objectives, we used two digital tools, which are based on many years of research. The first is Depthmap, which allows to convert layouts in the second dimension to the extension "DXF" and fill the open areas of those layouts with a grid of points. Once the graph is accomplished, the researcher can do various analyses of global and local measures (Bellal & Frank, 2003). The second is Agraph. After surveying the selected building and using Agraph, we drew a justified graph, which showed different axial movement relations and leads us to distinguish between topological spaces and properties of the spatial system.

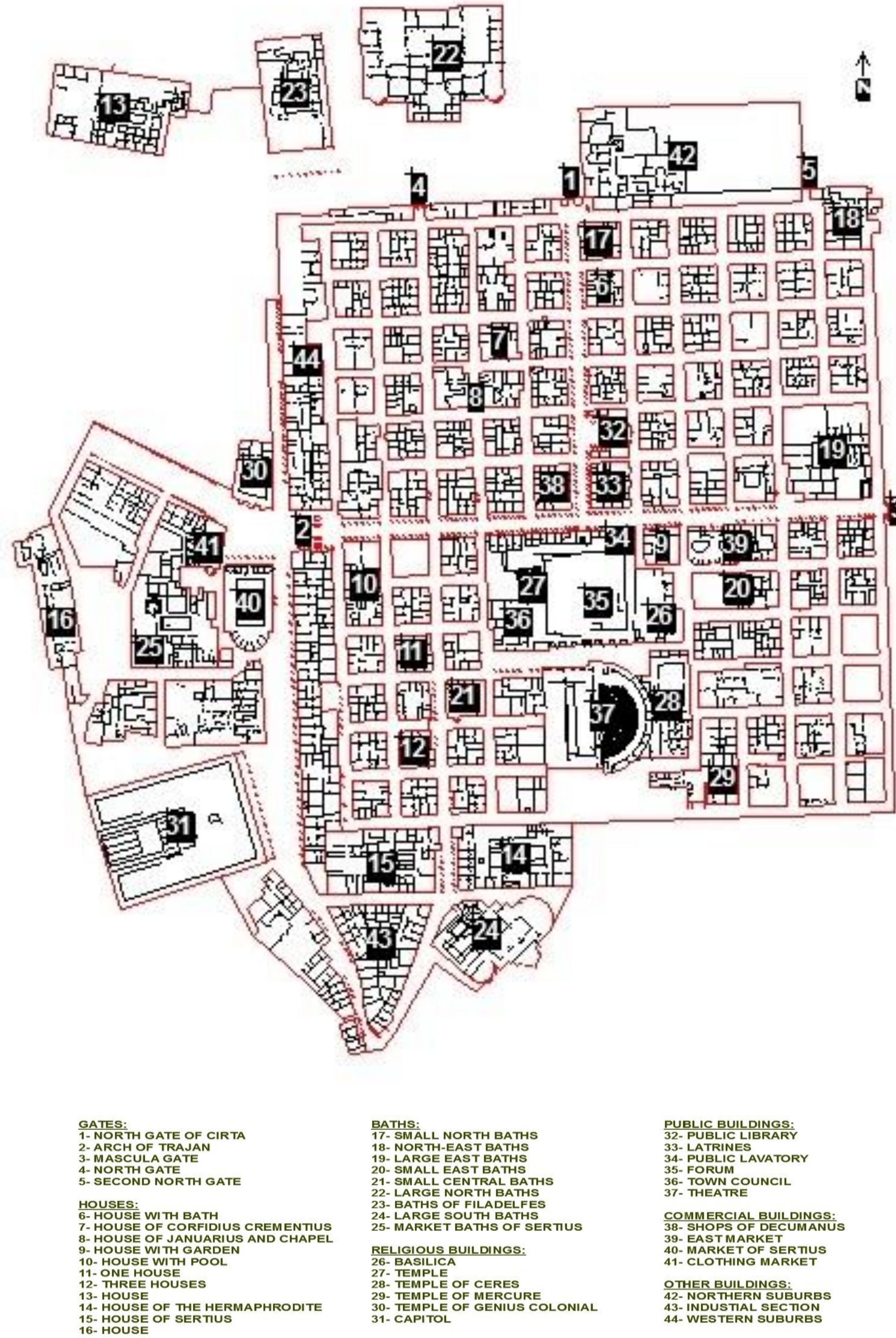
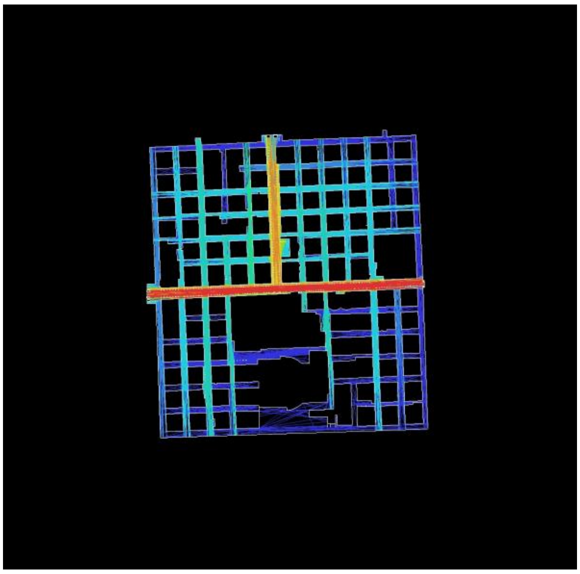


Figure 5. Selected studied zones from the urban composition of the ancient town of Timgad (ZONE 1 + ZONE 2) (Based on plan of Chergui (2011) cited in the website of the UNESCO, plan of Courtois (1951), plan of Lassus (1969), and all outer lines with dark-red color which are our actualizations based on our visits and observations on the site (2020))



6 (a)

6 (b)

Figure 6. Axial map of Timgad: (a) ZONE 1. (b) ZONE 1 + ZONE 2.

Table 1. Axial map indicators of integration and connectivity

	Integration			Connectivity		
	Minimum	Average	Maximum	Minimum	Average	Maximum
ZONE 1	9.08179	0.12566	28.313	9	5383.06	16664
ZONE 1 + ZONE 2	9.56338	0.04421	23.800	7	4977.5	21601
The Difference	0.48159	-0.08145	-4.513	-2	-405.56	4937

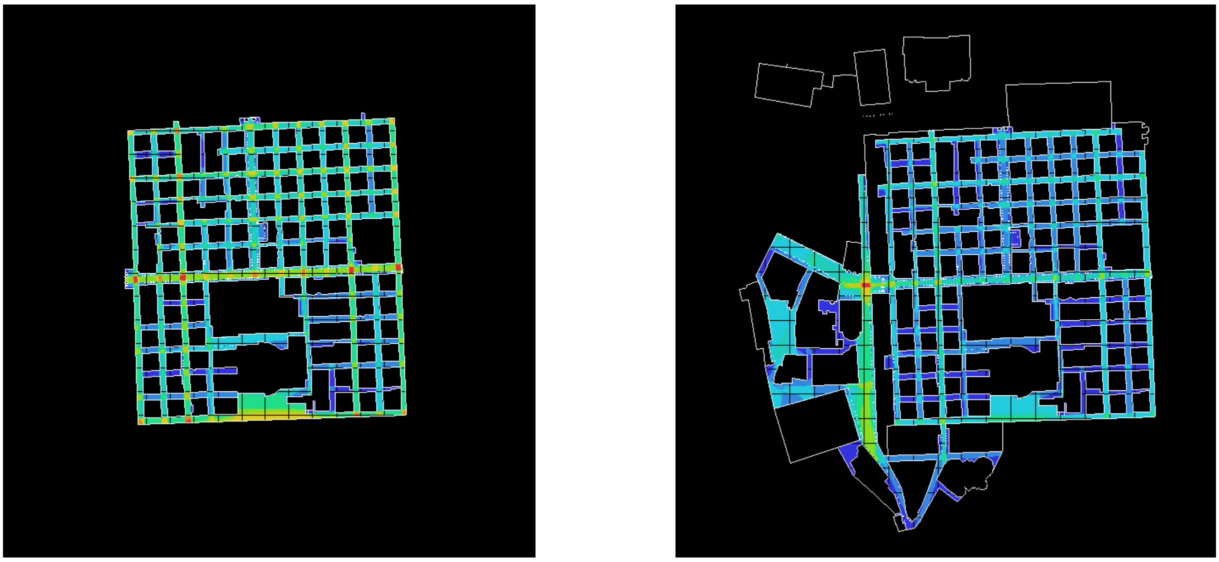
4. RESULTS AND DISCUSSION

4.1. *Axial map analysis*

Using Depthmap, Fig.6 and Table 1 were produced as the result of an axial map analysis of Timgad of selected studied zones.

Considering integration as a global property means that we treat destinations which are more accessible as more integrated, whereas inaccessible destinations are less integrated. This can be examined using the axial map. In the axial map, lines are colored red, orange, yellow, green, blue, and indigo to indicate measurements from the highest to the lowest levels of accessibility. Fig.6 makes clear that within ZONE 1 and ZONE 1 + ZONE 2, the axis Mascula gate to Arch of Trajan was the most integrated destination, and referring to Table 1, it contains the maximum value which equals 28.3131, followed by the axis of the north gate of Cirta, which leads to the forum. Within ZONE 2, the destination starting from the Arch of Trajan to the northwest appears to have been highly integrated, followed by the north axis to the capitol. This would explain why the maximum difference value of integration equals -4.513, which indicates a decrease from 28.313 to 23.800. Destinations behind the forum, the theatre, and the market baths of Sertius appear to have been less integrated within ZONE 2.

Analysing the axial map in terms of connectivity as a local property means to go from origin to destination, which requires that we select the streets through which to pass. As suggested by Fig.6, within both zones, more possibilities of choice were made possible in the northern part of the axis around the Mascula gate above the Arch of Trajan in comparison with the area to the south of this axis. The small size and simple topology of the urban islands provide the reason for this, which is clear when compared with the opposite area south of that axis, which is the location of big and complex urban islands, which can be traced back to the western and the southern expansions within ZONE 2. Referring to Table 1, the average value of connectivity equals 5383.06, despite decreasing to 4977.5 within the axial map of ZONE 1 + ZONE 2. This can be attributed to the previously stated reasons, but it also indicates the high degree of destination choice, especially in the northern part of the previous axis, and the western expansion in the axis of the capitol within ZONE 2.



7 (a) 7 (b)

Figure 7. Visibility graph of Timgad: (a) ZONE 1. (b) ZONE 1 + ZONE 2.

Table 2. Visibility graph indicators of control and point depth entropy

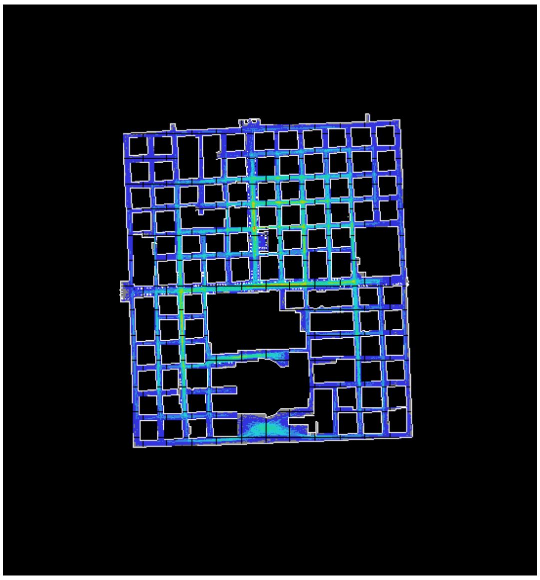
	Control			Point Depth Entropy		
	Minimum	Average	Maximum	Minimum	Average	Maximum
ZONE 1	0.09858	0.00217	1.83783	1.26564	0.00377	1.58878
ZONE 1 + ZONE 2	0.11695	0.16165	2.0695	1.41398	0.31792	2.25168
The difference	0.01837	0.15948	0.23167	0.14834	0.31415	0.6629

4.2. *Visibility graph analysis*

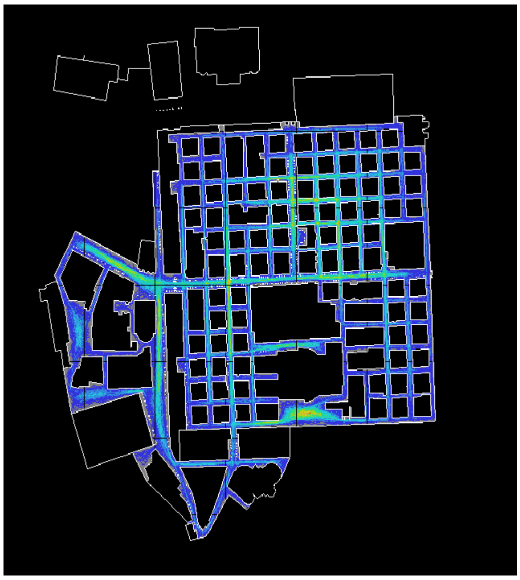
Using the Depthmap program, Fig.7 and Table 2 were produced as the results of a visibility graph analysis of Timgad of selected studied zones.

The ease of movement in that setting can be determined by considering the visibility graph; the size of the value reflects the standard of the ease of movement (low number indicating a high level of ease of movement, and a high number indicating a low level of ease of movement) (Pinelo and Turner, 2010; Guedouh and Assassi, 2020). The indicator of control as a local property measures the degree of control of a specific space in consideration of neighbouring spaces. Thus, regarding Fig.7 (a), within ZONE 1, the Mascula gate axis to the Arch of Trajan has high values of control, especially at the intersection points indicated by the red colour; this is demonstrated in Table 2, which makes clear that the maximum control value equals 1.83783. This is also true to a lesser extent at the intersection points north of this axis, as well as the area south of this axis. Regarding Fig.7 (b) within ZONE 1 + ZONE 2, the most important control point, indicated in red on the visibility map, is at the intersection of three axes: the axis of the Mascula gate to the Arch of Trajan, its north-west expansion axis, and the axis north to the capitol, which in Table 2 holds the high value of 2.0695, which suggests that the areas in the western direction became more accessible, and this is also confirmed via the difference in the average value of control, which equals 0.15948.

Point depth entropy as a global property allows us to explore the measurements of the distribution depths frequency. Fig.7 (a) reflects that within ZONE 1, the depths are represented in blue because they are especially distributed in the southern part, left and right to the forum and the theatre where we generally find different houses and some secondary equipments. Meanwhile, the northern part is the shallowest; this part is divided by the main entrance lane, which is the axis of the north gate of Cirta to the forum, where the frequency of visual relations is high. Regarding Fig.7 (b) within ZONE 1 + ZONE 2, with the creation of new axes, the ZONE 1 becomes deeper than the new expansions. As can be seen in Table 2, within both zones, the average value of point depth entropy was low, which means that the urban system allows for ease of movement, and to a lesser extent in the new expansions due to the irregular forms, big sizes, and non-geometric positioning of urban islands.



8 (a)



8 (b)

Figure 8. Agent analysis of Timgad: (a) ZONE 1. (b) ZONE 1 + ZONE 2.

Table 3. Agent analysis indicators of gate counts and first point moment

	Gate Counts			Point First Moment		
	Minimum	Average	Maximum	Minimum	Average	Maximum
ZONE 1	1	10.0066	72	14.7148	136479	706277
ZONE 1 + ZONE 2	1	7.02268	60	135.296	140162	910257
The difference	0	-2.98392	-12	120.5812	3683	203980

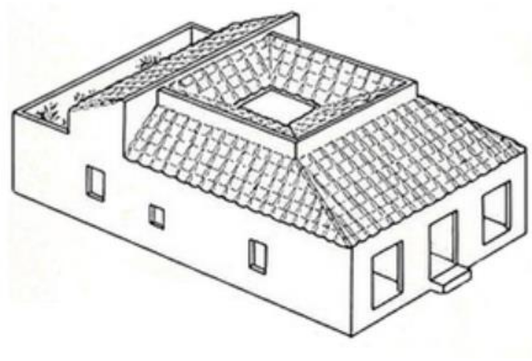
4.3. *Agent analysis*

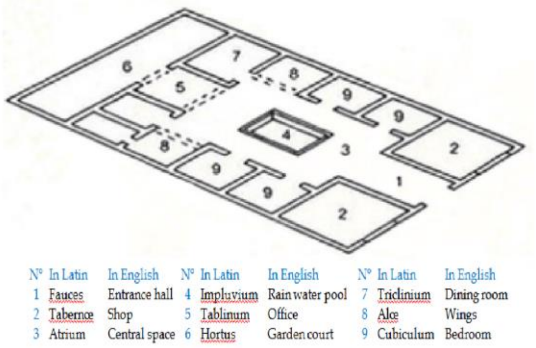
Fig. 8, and Table 3, are both the result of an agent analysis of selected studied zones (both were created using Depthmap).

The theory of *embodied space* is an agent-based model that explains the interaction between individual and environment in relation to learning and memorisation of different environments; it can be explained this way: "*The Agent model starts from the irreducible elementary actor in the system, that is the individual, and present[s] the visual dynamics that direct his movement aiming to understand and reproduce the process of inhabitation and occupation in space*" (Al_Sayed etal., 2014).

Fig.8 (a) indicates that agent analysis of ZONE 1 shows that the planning of the Trajan colony led individuals to use the town's principal axes, mainly the axis of the north gate of Cirta to the forum and the axis of the Mascula gate to the Arch of Trajan, which are represented by their green colour. This is confirmed by the average of gate counts in Table 3, which has a value of 10.0066, which represents more traffic between them, and more traffic from them to the centrally located, important building of the forum. Behind that, we see the theatre where we find interstitial spaces colorized with light blue near its longitudinal sides, which enables us to detect big rings wayfinding. We note also that other important buildings are located near those axes, such as that of the public library. The rest are coloured dark blue, which indicates that individuals made their own direction to their own houses, which is confirmed by the data presented in Table 3. This is confirmed by the difference between the minimum value of the point first moment indicator of 14.7148 and its maximum value of 706277.

Fig.8 (b) suggests that within ZONE 1 + ZONE 2, agent analysis shows that three new axes, the axis Mascula gate to the Arch of Trajan, its north-west expansion axis, and the axis north to the capitol, are light-green in colour, which makes sense given the new western expansion. This can be detected easily by the individual and new southern expansion to the south side of the theatre, which became more important than its north side, where it is possible to detect more big wayfinding rings; this explains why the gate counts decrease to the average value of 7.02268, and the average difference value of 3683 of point first moment is quite small.





9 (a) 9 (b)

Figure 9. Typical roman atrium house sample: (a) Perspective, (b) Layout
Source: https://arh342.weebly.com/rooms-in-the-domus.html

4.4. Convex map

Fig. 9 represents the perspective and the layout of a sample of typical Roman atrium house, as the house is one of the the most important elements for any town. We aim from this example to affirm the efficiency of the use of convex map for deducing the genetic domestic space of archaeological houses. This prompts us to carry out architectural surveys in a comparative study between the Roman dwellings of Timgad to reach original results in the next future papers.

Fig. 9 (a) shows the cuboid volumetric composition of this Roman house sample, as it was characterized by three types of access: the top hatch, the backyard, and the sloping roof. In Fig. 9 (b) we observe that the layout of this Roman house sample appears as a fanned plan of regular geometric geometric shape and is characterized by central distribution from the atrium (central space), which contains the impluvium (rainwater pool). The cubiculum space (bedroom) has the largest number of spaces, followed by the tabernœ (shop) and the alœ (wings). After those, in terms of surface space, the hortus (garden court) and the atrium are the biggest, followed by the tabernœ.

Fig. 10 reflects the spatial configuration of the justified graph of this typical Roman house based on convex map logic (produced using Agraph).

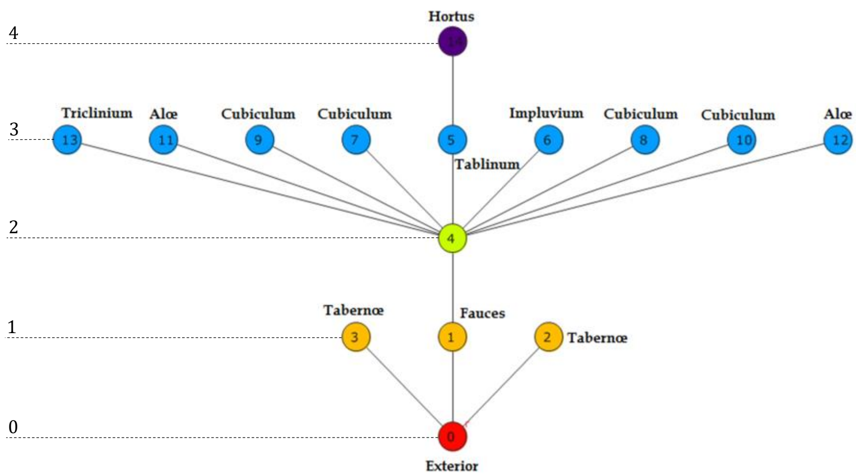


Figure 10. Justified graph of the typical Roman atrium house

Fig.10 was produced using Agraph. It depicts the justified graph of the spatial composition of a sample house, where spaces are called nodes, and the nodes start from the exterior node expressed by the carrier or rood node. Fig.10 shows that the justified graph of this house is made of four levels of transition and five horizontal dotted lines of a tree-like structure and alpha-shaped and semi-deep. This leads to the centralization of the dominant space, which is the atrium, which has direct visual relationships, except the hortus which is separated by the tablinum (office). We note also that the two spaces of the tabernœ are included within the cuboid volumetric composition of the house but isolated from its internal spatial composition. This spatial composition leads also to a partial breakdown of movement and the visual relationships do not tend to 0.

Fig.11 represents the justified graph of the topologic types of space of this typical Roman house sample in terms of accessibility and movement relationships (the image was produced using Agraph):

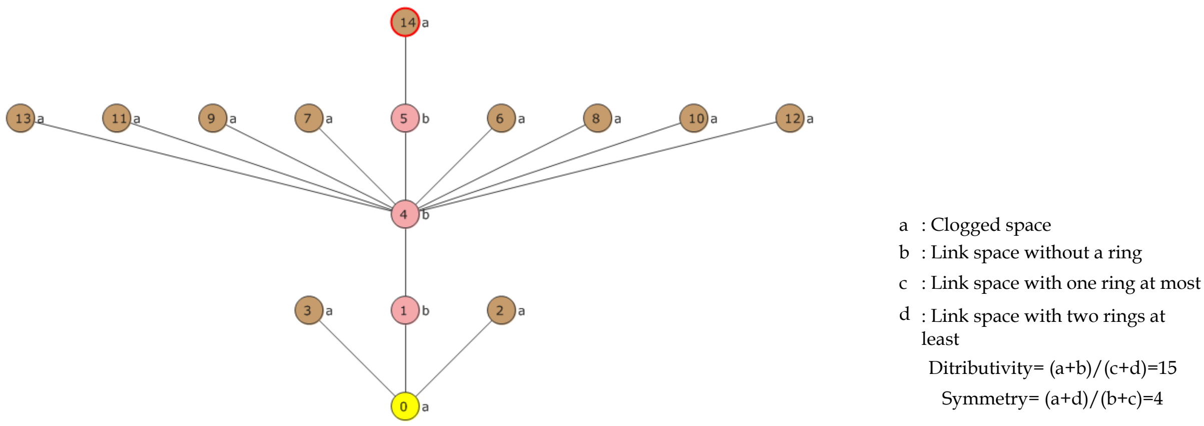


Figure 11. Topologic types of the typical Roman atrium house

Fig.11 indicates the topologic types of space of this house based on the relations between each space with each other space. The topologic types of different nodes are divided into two types: 80% of Type A, and 20% of Type B: this means that the spatial configuration of this house does not allow free movement, and it was necessary for occupants to return to the atrium to move to most of the other spaces (except the hortus and the two tabernœ spaces).

Furthermore, as the values of the distributivity and symmetry indicators are bigger than 3, we can say that the spatial configuration of this Roman house is characterized by non-distributivity, symmetry, and isolation.

The data in Table 4 were produced using Agraph. The table contains the results of an analysis of the justified graph indicators of this typical Roman house sample.

Table 4. Results of justified graph analysis of the typical Roman atrium house sample

N°	Space	TDn	MDn	RA	i	CV
0	Exterior	36	2	0	4	2
1	Fauces	27	1	0	7	0
2	Tabernœ	49	3	0	2	0
3	Tabernœ	49	3	0	2	0
4	Atrium	20	1	0	15	9
5	Tablinum	31	2	0	5	1
6	Impluvium	33	2	0	4	0
7	Cubiculum	33	2	0	4	0
8	Cubiculum	33	2	0	4	0
9	Cubiculum	33	2	0	4	0
10	Cubiculum	33	2	0	4	0
11	Alœ	33	2	0	4	0
12	Alœ	33	2	0	4	0
13	Triclinium	33	2	0	4	0
14	Hortus	44	3	0	3	0
	Min	20	1	0	2	0
	Mean	34	2	0	5	1
	Max	49	3	0	15	9

TDn: Total Depth (TD) for actual node

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

RA : Relative Asymmetry RA=2*(MD-1)/(K-2)
i : Integration Value i= 1/RA
CV : Control Value
K : Number of nodes
H : Difference Factor H = - (a/t * ln(a/t) + b/t * ln(b/t) + c/t * ln(c/t))=0
H* : Relative Difference Factor H* = (H - ln2) / (ln3 - ln2)=-0
a : Max RA
b : Mean RA
c : Min RA
t : a+b+c

Table 4 represents the set of links between each node and other nodes in terms of their depth. Firstly, the values in the table show that the atrium is the shallowest space because it holds the minimum value of 20, and the tabernœ is isolated from the internal spatial composition of the house sample, so, the hortus is the deepest space because it holds the maximum value of 44. Secondly, as the mean depth is used to calculate the number of steps within the spatial system of the house sample, its values show that the difference between the mean depth value of the fauces (entrance hall) as the first space, which equals 1, and the mean depth value of the hortus as the final space, which equals 3, is not big. This means that there is a lack of stages or levels to reach the deepest space in the house. Thirdly, as the relative asymmetry is used to determine whether the spatial configuration of the house sample is shallow or deep or moderate in shallowness, all values equal 0, which means that the spatial system of the house sample is shallow. Fourthly, *integration* in this context is a global measurement that represents the relative centrality of spaces, and in this case its values are greater than the value of 1, which means that the spatial structure of the house sample is segregated. Fifthly, as the control value is a local measurement that is used to know the level of controllability of each space for the rest of the spaces, its values, in this case, suggest that the atrium is distinguished by its strong controllability compared to other spaces because its value is greater than the value of 1; in measures of controllability it is then followed by the tablinum. Sixthly, the difference factor is calculated to differentiate between integration values of three or more spaces in order to know the level of difference in term of transition possibilities; in this case, its value equals 0, which means that the spaces of the house sample are segregated. Seventhly, the relative difference factor was calculated to determine whether the system is homogeneous or not; in this case, its value also equals 0, which means that the house sample is characterized by a heterogeneous system. Finally, the following is the order of integration of house functions; the greater integration value determines the location of the most integrated space: tabernœ = 2 < hortus = 3 < exterior = cubiculum = impluvium = alœ = triclinium = 4 < tablinum = 5 < fauces = 7 < atrium.

5. CONCLUSION

The analyses here yielded several results. In particular, our analysis has led us to the following considerations. Firstly, the axial map leads us to differentiate between *urban public spaces*, such as different main axes and the space between forum and theatre, and *semi-urban public spaces*, such as the streets leading to houses. However, we note the lack of the exterior private space. Secondly, the visibility graph also helps us to deduce that "control" as a military concept likely informed within ZONE 1, while within ZONE 2 we can recognize a lack of interest in that area by virtue of the irregular geometry and complex topology which characterize the new expansions.

Thirdly, in our case study, the results of the agent analysis lead us to better understand the meaning of individual wayfinding, learning, and memorizing, by identifying the orthogonal grid present within ZONE 1, and by detecting the different logic of walkability lanes in new expansions west and south of the original boundary, which means that in case of getting lost, the wayfinding urban landmarks such as the main axes, forum, and capitol can be good guides to draw up new wayfinding routes and procedures. Fourthly, the results of software analysis indicates that what is called southern *cardo* has not similar numeric results than what is called nothern *cardo,* but it has similar numeric results than other secondary axes. It means that, within the limits of the studied zones, it is digitally wrong if we speak about what is called southern *cardo.* Fifthly, the convex map analysis shows that the typical Roman house sample was divided into a minor part containing isolated spaces of tabernœ and principal access, and a major part which contained various spaces expressed by different functions and characterized by the centrality of the atrium and the backgrounding of the hortus, which can be determined by virtue of topologic movement and direct visual relationships due to the regular geometry that complements the exterior urban regular topology and geometry. If we delete the exterior in the analysis of the convex map, we'll find that the difference between the indicator values of the spatial structure which contain the exterior node and the indicator values of the spatial structure which do not contain the exterior node is big, this means that the architectural program of spaces focuses on the relation between the inhabitant/guest, which is clear through the inner position and big size of the triclinium space, for example.

Thus, using Depthmap and Agraph helped us to analyse the spatial configuration of the urban planning of the ancient town of Timgad, and architectural space of a typical roman house sample, through the framework of a diachronic study to quantitatively understand the different indicators of urban and architectural properties, which could not have been determined without the help of these digital tools. Then, we affirm the efficacy of space syntax programs in the accurate analysis of exterior or interior spaces, and relationships between them within archaeological sites, and then we record, referring to space syntax approach, the necessity of next future papers based on a quantitative comparison between accurate surveys of spatial configurations of Roman buildings taken from the archaeological site of Timgad, which will leads us to other original results and conclusions.

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