The visibility graph:

An approach for the analysis of traditional domestic M'zabite spaces

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Abstract

This paper examines domestic spatial arrangements of the Berber people of the M'zab. It covers the areas of Ghardaia, Beni Isguen, El Ateuf, Melika and Bounoura - the five walled towns or Ksours of the M'zabite league. In his famous study of the Kabyle Berber house, the late Pierre Bourdieu underlined the symbolic significance of domestic spatial arrangement. A simple rectangular form on plan, the Kabyle house is divided into two parts, a division which becomes the basis for an elaborate system of binary oppositions - dark versus light, nature versus culture, male versus female. In configurational terms the house is integrated and has a shallow 'core'. By contrast the distinctive feature of the M'zabite house is that it is inward-looking, with rooms distributed around a small internal courtyard, commonly on two floors. This is combined with a sharp division between male and female quarters and between spaces for visitors and those reserved for the family. The access pattern is characteristically tree-like and reveals two main 'genotypes', one centred on the Wast Eddar, the ground-floor living space, the other on the Ikoumar, an upper-floor 'portico' used for various female and family activities.

Visibility mapping (depth map), applied to a cross-sectional sample of the M'zabite houses, further clarifies the internal structure of the dwelling. Local measures, such as the clustering coefficient, and global ones, such as point depth entropy, point to a high level of visibility in many of the interiors, especially in and around the Wast Eddar, the Ammas N'Tadart (a central space), the Ikoumar and the Tigharghart (upper courtyard). This is in spite of the irregular geometry on plan and the associated junctions and turning points, which sometimes lead to a loss of visual fields. Interestingly, the Tisifri, a ground floor room used for women visitors, tends to be well-connected visually to neighbouring spaces. This would appear to be due to its strong physical and functional link with the central courtyard, the Wast Eddar, which is the hub of female activity. This is very different from the men's spaces, such as the Houdjrat (on the ground floor) and the Aali (on the first floor), which are highly enclosed. The Skifa (entrance hall), is always enclosed, peripheral and private (see cluster coefficients and point depth entropy), reflecting its role of restricting entry and breaking the field of view. Other highly bounded spaces include the Tazeka (room) and the Tazeka N'El Aoulat (storage room), which are commonly to be found at first floor level.

These visibility characteristics, like the spatial genotypes, are widely repeated across the sample, irrespective of location. It is notable, however, that Ben Isguen, the most sacred settlement of the five that comprise the M'zabite league, yields both the highest and the lowest values for clustering coefficient and entropy. El Ateuf, the most ancient of the settlements, by contrast, produces values that are clustered in a much narrower band. Bearing in mind the morphological consistency across the sample, it is difficult at this stage to explain these cross-settlement differences. However, further study of room-use, orientation, and the functional and physical relationship between the house and the settlement may be informative.

1. Introduction

This paper is concerned with an investigation into the houses of the Berber M'zab region. This concern has been prompted by the existence of a particular morphological feature, the "spatial configuration" of the houses themselves. It tends to question the relationship between the structuring of space and the apparent correlation between the spatial patterns and the system of social relations within the M'zabite house. From this simple starting point, inferences can be made about the way domestic space supports family life and house organisation. In his study of the Berber house, Pierre Bourdieu has underlined the significance of the spatial arrangements [1]. Space division is accomplished according to a balanced division between binary oppositions: inside/outside, public/private, etc., which reflect a division of the world into male and female spaces. However, previous studies by the authors have identified differences in the spatial configuration of M'zabite domestic spaces in comparison to other Berber houses [2]. The most distinctive feature of the M'zabite house is that it is a highly introverted, tree like configuration with a strong spatial genotype [the Wast Eddar, the Ikoumar, and the Tigharghart], findings which were related to differences in attitudes and that were different from what Bourdieu was talking about. In this paper, the relation between visibility and permeability are examined in order to pinpoint more precisely the defining features of the key spaces of the genotype that single these out from the other spaces in the houses.

2. The M'zabite house

The M'zabite traditional domestic space, which is the subject of this paper, refers to the type of architectural space that was built between the eleventh and fourteenth centuries in the M'zab valley, a region of the Sahara in Algeria. The examples are drawn from the five Ksours [Ksar in singular] that form the "pentapolis", five walled towns of varying size and importance comprising 4487 houses established on an area of 67 ha [3]: El Ateuf [1011], Bou Noura [1046], Ghardaia [1053], Melika [1124], and Beni Isguene [1347]. [3] These settlements are built in close proximity to one another. All lie between a latitude of 32°30' north and a longitude 3°45' east.

3. General description of the M'zabite house

The following description of the houses is based on an examination of the plans of 70 houses taken from the five settlements that form the pentapolis of the M'zab valley; 24 houses from the Ksar of Ghardaia, 19 houses from the Ksar of Beni Isguen, 12 houses from the Ksar of El Ateuf, one house from Bounoura, and finally 14 houses from the Ksar of Melika [see the plans of the houses in the annexe]. Access from the street to the house is always through the Skifa, or chicane, which plays an important role in the functioning of the house. Opposite the front door, a wall protects the Wast Eddar (main living room) from the view of possible visitors. The door leading to the Wast Eddar is set off from the axis of the front door, and that front door gives direct access to the male reception quarter: the Houdjrat on the ground floor level or the Aali on the first floor. On one side of the Skifa, there is a room used for keeping the domestic animals. Sometimes in this chicane, there is a recess in the wall in which a hand-quern is kept, that allows easy access for male neighbours who do not have one [4]. Also, water jars used to be kept in this space so that the professional water porters could deliver water to the individual houses without exposing the women to their presence. In most of the examined houses, a morphological feature may be noted; two separate pathways exist to the interior. The first or family path leads to the Wast Eddar, the large living space surrounded by small rooms. A staircase links the ground floor to the first floor, which consists of multi-functional rooms, the Ikoumar or arched portico and the Tigharghart or the upper courtyard. Another staircase links the upper floor to the Stah or the terrace. The second pathway leads up from the chicane through another staircase to the Aali [a separate quarter reserved for the male visitors]. The Aali, which is very richly furnished and decorated, consists of one large room, usually with a small window giving onto the street. Sometimes, there is a bedroom annexe to this male reception room.

The Wast Eddar, as mentioned earlier, is by no means the largest space in the house. No furniture exists in it except for the loom, the built in shelves for the cooking utensils and an oven that occupies one side of it. The Tisifri, [women's living room] gives onto the Wast Eddar. It is used for women visitors and it is to this room that the women move after giving birth. The other rooms that give onto the Wast Eddar do not have specific usage. The dimensions of the rooms are modest, they barely exceed two metres in width whereas the length varies and may be relatively important. The toilets are usually located in a remote corner off the Wast Eddar. The house is equipped as well with a traditional bathroom. From the Wast Eddar, a staircase leads up to the first floor, which consists of the Emess Enej or the upper centre, surrounded by small rooms. The ceiling height is very modest; less than two metres twenty centimetres, and in some cases [old houses] less than two metres. On the first floor the whole family uses the Ikoumar for sleeping at night during the summer. It is here that the women do their washing, sometimes cooking or take their afternoon coffee or tea alone or with their female visitors [5]. In most of the analysed houses the Ikoumar or arched portico is oriented towards the south or the southwest. Another staircase leads up from the Emess Enej, to the Stah or terrace, access to which is exclusively reserved for women.

4. Visibility mapping

In architectural composition, a process of visualisation of space as being potentially occupied by users and sequences of events is essential, though not necessarily conscious. Hill. J, [6]: *"The architect and user both produce architecture, the former by design, the latter by inhabitation. As architecture is designed and experienced, the user has as creative a role as the architect."* In this sense, the visibility graph is a tool with which we can begin consciously to explore the visibility and permeability relations in spatial systems. The relation between visibility and permeability is a vital component of how houses work spatially and are experienced by their occupants.

The application of visibility graph analysis to building environments was first introduced as early as 1980 by Braaksma and Cook [7]. They calculate the co-visibility of various units within an airport layout, and produce an adjacency matrix to represent these relationships, placing a "1" in the matrix where two locations are mutually visible, and a "0" where they are not. From this matrix they propose a measure to compare the number of existing visibility relationships with the number which could possibly exist, in order to quantify how usefully a plan of an airport satisfies a goal of total mutual visibility of locations.

The vga can help to investigate the configurational relationships of domestic space through "depth map", a programme which is designed to perform visibility graph analysis of spatial environments [8]. The program allows us to import a 2d layout in drawing exchange format [dxf], and to fill the open spaces of this layout with a grid of points. Once the graph has been constructed we may perform various analyses of the graph. The measurements of local and global characteristics of the graph for every analysed house are of interest from an architectural perspective. In fact, these measurements can lead us to describe the house's spatial configuration with reference to accessibility and visibility. The visibility graph properties may give clues to interpret manifestations of spatial perception, such as way finding, movement, and space use within a building or a house. Note that we have discussed a graph in terms of visibility, and therefore implicitly at eye level, taking an isovist at any height above the floor can form the visibility graph. As Hanson writes [9]:

"*In moving around in buildings, people orientate themselves by reference to what they can see and where they can go. In looking at the visual and volumetric qualities of architecture, we need not be constrained by the pragmatics of everyday space use and movement. Indeed, we should not be, since architectural speculation almost invariably brings into play the relationship between visibility [what you can see] and permeability [where you can go].*"

5 Graph construction

The graph is made by depth map. The programme attempts to find all the visible locations from each grid location in the layout one by one, and uses a simple point visibility test radiating from the current location to achieve this. As each location is considered, a vertex is added to the graph for this point, and the set of visible vertices is stored.

Depth map colours values by using a spectral range from indigo for low values through blue, cyan, green, yellow, orange, red to magenta for high values [10]. For instance the measure known as *Point depth entropy* corresponds to how easy it is to traverse a certain depth within a system; low values correspond to low disorder, that means it is easy to move around and high values correspond to high disorder, which means that it is hard to move around. Concerning the clustering coefficient measure, low values occur where new areas of the system may be discovered so we tend to have high values at the corners, on the turning points i.e. the stairs or walls. The user may change the bounds for this range, or choose to use a greyscale instead, where black represent low values and white represents high values. In the current study, we consider each measure from the point of view of each vertex in the graph and we examine the pattern of their distribution across systems.

6. Graph measurement

After producing a vga for any given spatial environment we can analyse it by making use of some of the many measures developed for investigating graph properties. The analysis of the graph is split in two types: global measures [which are constructed using information from all the vertices in the graph] and local measures [which are constructed using information from the immediate neighbourhood of each vertex in the graph]. In this study we will focus on two measures of graph structural properties. These are the local property, clustering coefficient [cc] and neighbourhood size [ns], and the global property point depth entropy [pde]. Once the measures have been calculated, these and derived measures will be used in a statistical package.

The clustering coefficient and point depth entropy have previously been used together to characterise graph systems as a whole [12]. In the section that follows, we describe the measures in detail, discuss their likely usefulness and implications, and present some cases based on the analysis of houses taken randomly from the Mzab sample.

- Clustering coefficient

The clustering coefficient [cc] gives a measure of the proportion of intervisible space within the visibility neighbourhood of a given point. It is defined as the proportion of vertices which are actually connected within the neighbourhood of the current vertex, compared to the number that could possibly be connected.

- Neighbourhood size

The neighbourhood of a vertex is the set of vertices immediately connected through an edge. We can plot the values of neighbourhood size for all the physical locations represented by vertices in the graph.

- Point depth entropy

In addition to calculating measures such as mean depth, the point depth entropy [pde] allows us to explore measures based on the frequency distribution of depths. Calculating point depth entropy [pde] can give an insight into how ordered the system is from a location. Point depth entropy [pde] is the least number of edges that need to be traversed to get from one vertex to the other. Point depth entropy [pde] for a vertex is simply the average of the shortest path lengths from that vertex to every other vertex in the system, and so represents an average of the number of turns required for any journey within the system.

-Legend

In the following section we should use in Tables [1-5] the following terms that stand for their corresponding measures:

INT: Integration	GS: Graph Size	ReE: Relativised Entropy.
NS: Neighbourhood Size	C: Control	CC: Clustering Coefficient
PDE: Point depth entropy	MD:Mean depth	FD: Far distance

6.1 Graph analysis: Ghardaia sample

As a built example, we consider the configurational characteristics of the spaces in the Mzab traditional houses. We construct the visibility graph and Figures [1-10] show the pattern of Clustering coefficient and Point depth entropy values produced for the interior spaces of houses [1-2, 4, 9, and 11 inclusive]. To create the Figures we used a 0.2 grid of vertices covering all accessible areas in every house. Concerning the whole Ghardaia sample, Table 1 shows some important results that can help to better understand these houses. For instance when we look at the key global properties [Point depth entropy] or at the local properties [Clustering coefficient] some interesting points ought to be discussed.

The global property Point depth entropy indicates that the values for Ghardaia range from 0.7163 to 1.1615 with 50% of the houses at the lower scale of the range. Houses 5, 7, 9-10, 13, 15-17, and 21-24 inclusive turn out to have the lowest values in the sample, which means low disorder when traversing the houses from one vertex to another; that is to say, the house are easily accessible in terms of permeability as well as of visibility fields. It also demonstrates that the areas of the visual fields change continuously with movement, as surfaces disappear and others come into view. House 24 turns to have the lowest value 0.7163, which means that it is open to visual fields from the interior and views were arranged across the Wast Eddar and the Tigharghart. This house is of a rectangular shape with the rooms distributed around a regular shaped Wast Eddar, thus, offering a multi-directional field of views as well as an easy permeability within the spatial configuration. The Ghardaia sample medium range values is represented by Houses 2, 3, 6, 12, 14, and 18-19 inclusive. The remaining 20% houses represent the highest scale of the range, with House 20 having the highest value of 1.1615. Thus the accessibility/visibility model is minimised within this house. The geometry of these houses tends to be irregular in shape which helps to create many junctions and turning points within the spatial structure, leading to a loss of visual fields and thus, clustering most of the rooms.

One point ought to be discussed here, the morphological characteristics of the sample of houses show a lack of formal and geometrical properties that suggest conscious planning and design, and the aggregation of spaces within the configurations is extremely irregular, appearing disorganised and chaotic. It follows from these measurements that nearly 80% of the houses do show some ease in terms of accessibility and visibility which means the opposite of what one might expect from a superficial visual inspection of the plans.

Concerning the local property or Clustering coefficient measure, the results also show that the most social spaces within the houses, the Wast Eddar at ground floor level and the Ikoumar and the Tigharghart at first floor level offer multidirectional fields of view and therefore low Clustering coefficient values [See Figures 2, 4, 6, 8, and 10]. The values for the whole sample range from 0.6936 to 0.8409. On the other hand, the most private spaces; the bedrooms, the Tisifri and the other rooms are highly clustered which means high values corresponding in the visibility graph to the colours ranging from yellow to magenta. For instance, House 11 turns out to have the lowest Clustering coefficient of all, with a value of 0.6936, thus, offering a wide range of field views when moving around the house. On the other hand, House 24 tends to minimise the spectrum of the field views inside the spatial configuration, with a value of 0.8409. The analysis we have made has not considered the relation of the houses to their context. Taking into account of the fact that external envelope of the houses in the Mzab has blank walls with few small openings, this will not raise questions with respect to visibility relations between inside and outside.

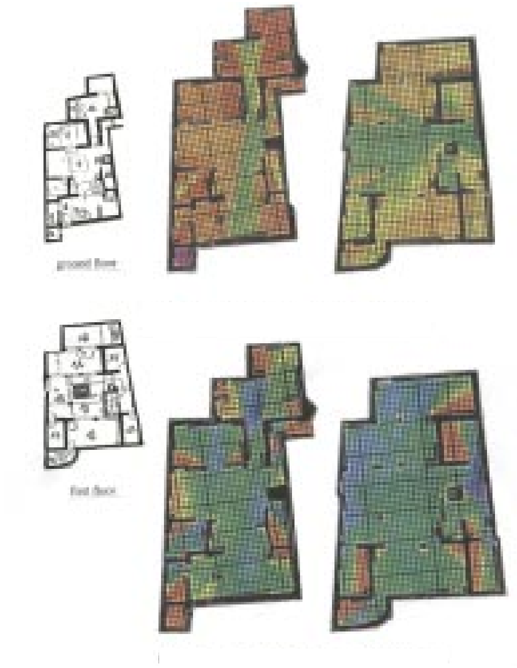
Working through the Ghardaia sample, it is interesting to see the openness and high level of visibility in many of the interiors, especially the Wast Eddar, the Ikoumar, and the Tigharghart [clustering coefficient]. This is in spite of the irregular geometry and associated junctions and turning points, which sometimes lead to a loss of visual field. Some features are puzzling. The point depth entropy of House 1 from the Ksar of Ghardaia is consistently high for the ground floor compared with the clustering coefficient, yet by contrast it is very low for House 2 from the same Ksar. Tazeka N'el Aoulet has an incredibly low level of disorder compared with the ground floor of the same house. One point of interest: the Tisifri, though an enclosed space, is commonly well-connected visually with neighbouring spaces, especially the Wast Eddar [see Houses 1-2, and 9 from the Ksar of Ghardaia]. This is very different from the men's spaces, the Houdjrat [House 2], and presumably reflects the fact that the Wast Eddar is pre-eminently the focus of female activity. The Skifa is always enclosed, peripheral and private [see the point depth entropy and clustering coefficient] reflecting its role of restricting entry and breaking the field of view. Other comparatively private spaces are the Aali [House 11], toilets, rooms, and storage room [House 2]. By looking at relationships at both a local and a global level, we hope to capture the experience of traditional space, and so visibility graph analysis may represents a step towards exploring the potential of users as designers of space, and as architects of their own experience of space as is our case of the Mzab.

Table 1: Visibility graph of Ghardaia Sample.

House	INT	NS	FD	GS	C	PDE	Re E	M D	C C
1	0.9478	301.75	0.2706	1014.4	0 .0047	1.0448	0.3653	2.0302	0.7174
2	0.9553	408.80	0.3036	1294.4	0.0030	0.9260	0.4307	1.8935	0.7206
3	0.9574	630.05	0.3545	1905	0.0019	0.9479	0.4126	1.8833	0.7251
4	0.9502	357.34	0.2701	1195.4	0.0032	1.0203	0.3822	1.9983	0.7634
5	0.9591	330.35	0.2523	766.25	0.0035	0.8487	0.4604	1.7187	0.8076
6	0.9519	251.89	0.2198	730.38	0.0044	0.9241	0.4284	1.8536	0.7855
7	0.9578	312.14	0.2651	721.50	0.0031	0.8163	0.4731	1.7119	0.8025
8	0.9465	457.50	0.3409	2044.7	0.0026	1.1092	0.3505	2.2304	0.7660
9	0.9604	312.14	0.2651	721.50	0.0031	0.8363	0.4731	1.6683	0.8025
10	0.9616	569.74	0.3300	1358.7	0.0025	0.8585	0.4556	1.7468	0.7576
11	0.9452	375.06	0.3141	1949.9	0.0029	1.0945	0.3624	2.2388	0.6936
12	0.9568	738.57	0.4103	2410.5	0.0014	0.9571	0.4218	1.9279	0.7824

Table 1 continued../

House	INT	NS	FD	GS	C	PDE	Re E	M D	C C
13	0.9637	1057.6	0.4350	2652.1	0.0011	0.8784	0.4431	1.7685	0.7945
14	0.9486	190.44	0.4354	578.62	0.0060	0.9421	0.4186	1.8986	0.7746
15	0.9637	242.75	0.2011	473.04	0.0040	0.7608	0.4918	1.5504	0.8049
16	0.9615	417.86	0.2798	981.55	0.0025	0.8150	0.4783	1.6836	0.7527
17	0.9596	860.53	0.4725	2844.4	0.0013	0.8967	0.4548	1.8770	0.7140
18	0.9500	279.02	0.4585	744.59	0.0046	0.9981	0.3871	1.9391	0.7825
19	0.9479	245.97	0.5167	845.48	0.0068	0.9082	0.4610	1.9505	0.7232
20	0.9418	325.78	0.2505	1020.3	0.0063	1.1615	0.3663	2.2635	0.7712
21	0.9639	492.85	0.6212	1131.7	0.0020	0.7911	0.4895	1.6438	0.7437
22	0.9503	153.56	0.4234	470.75	0.0062	0.8482	0.4788	1.8069	0.7073
23	0.9574	221.47	0.4443	525.93	0.0047	0.8240	0.4748	1.6881	0.8133
24	0.9644	286.05	0.5124	546.98	0.0040	0.7163	0.5310	1.5646	0.8409
Mean	***0.9559***	***409.13***	***0.3604***	***1205.3***	***0.0035***	***0.9135***	***0.4371***	***1.8556***	***0.7644***



Figures 1 and 2: Point depth entropy and clustering coefficient for house 1-Ksar of Ghardaia

Figure 9: Point depth entropy for house 11-Ksar of Ghardaia

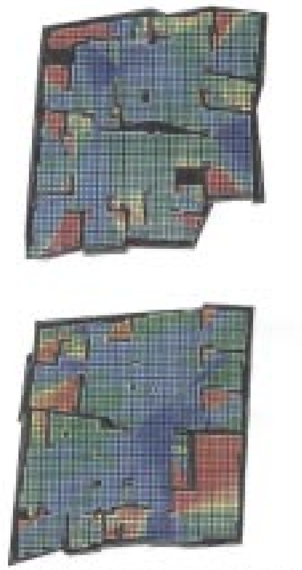


Figure 10: Clustering coefficient for house 11-Ksar of Ghardaia

6.2 Graph analysis: Beni Isguen sample:

As another built example, we consider the configurational characteristics of the spaces in the Ksar of Beni Isguen. We construct the visibility graph and Figures [11-12] show the pattern of Clustering coefficient and Point depth entropy values produced for the interior spaces of house one. To create the figures we used the same grid as in the sample of the Ksar of Ghardaia that means 0.2. Concerning Beni Isguen sample, Table 2 also shows some interesting results. For instance when we look at the key global property [Point depth entropy], one striking point emerges, in that, the houses present the extreme maximum and minimum values for the entire sample: House 11 turns out to have the lowest value of all with 0.6751 [that means that the relatively regular layout of the house helps one to move inside the spatial structure without any difficulty] whereas House 14 turns out to have the highest value of all, with 1.2687, which means high disorder and thus difficulty in terms of accessibility and visibility as well. This house tends to be of irregular shape with many junctions and turning point within the spatial structure leading to the clustering of most of the rooms. Again, the highest values indicate that it is hard to move around the interior spaces whereas low values correspond to an easy movement to a certain depth within the houses in terms of visual fields. 37% of houses [Houses 2-3, 5-6, 14, and 16-17 inclusive] have the highest values in the Beni Isguen sample. 21% turn to have medium range values [Houses 4, 13, 18-19 inclusive]. 42% of the houses present the lowest values in the range [Houses 1, 7-12, and 15 inclusive].

As far as the Clustering coefficient measure is concerned, the results also show that the extreme minimum value of the whole sample is found in in the Ksar of Beni Isguen. The most private spaces within the houses are highly clustered including the Tisifri whereas the Wast Eddar and the Ikoumar offer multidirectional fields of view and therefore low Clustering coefficient values [For example see House 1 Clustering and Point depth entropy graph]. Figure [12] shows the pattern of this measure produced for the interior spaces of House 1 in the Ksar of Beni Isguen. As for the whole sample, Table 2 shows that, 100% of the houses present relatively low values [these values range from 0.6859 to 0.8451 with a mean of 0.7746]. In fact, House 4 turns to have the lowest Clustering coefficient of all with a value of 0.6859, thus offering a wide range of field views when moving around the house. On the other hand, House 8 tends to minimise the spectrum of the field views inside the house, with a value of 0.8451. What do these figures imply? The houses in the Ksar of Beni Isguen, which is considered to be the sacred site of the entire M'zab valley, do not differ from the other Ksours' houses in terms of size, shape, the irregularity of layout and morphological character, specific room arrangements [spatial genotypes] or room use. The application of this local property measure highlights different aspects of the houses' layout, both within and between the analysed examples. Bearing in mind that this ongoing research does not seem yet to have reached the necessary depth for understanding and generalising from the phenomena under investigation, we try to adjust the balance between the description of the research methodology and our findings so as to give as much detail possible about results of the research.

After applying the visibility graph analysis tool to the houses of Ghardaia and Beni Isguen, a clear and consistent pattern starts to emerge which indicates first the clustering of private spaces [most of them are 'a' space type or dead-end] and secondly the wide range of visual field directions that the social spaces within the houses [being of 'b', 'c', and 'd' space types] offer to the potential inhabitant or user. For House 1 from the Ksar of Beni Isguen, the Tisifri is well-connected to adjacent spaces and offers multidirectional field of view especially in the case of the Wast Eddar. The graphs [point depth entropy and clustering coefficient] present almost identical space patterns as in the previous case of the Ksar of Ghardaia.

Table 2:Visibility graph of Beni Isguen sample

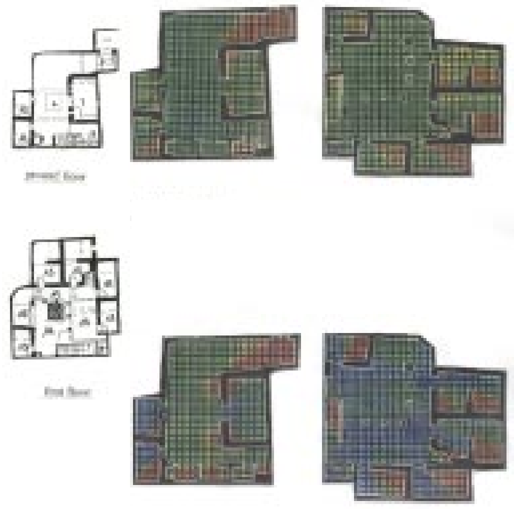
House	INT	NS	FD	GS	C	PDE	Re E	M D	C C
01	0.9580	312.06	0.2520	886.43	0.0034	0.8579	0.4596	1.7758	0.7594
02	0.9490	290.54	0.2496	949.20	0.0040	1.0270	0.3728	2.0066	0.7249
03	0.9453	302.76	0.2724	1209.0	0.0039	1.1038	0.3365	2.1291	0.7392
04	0.9547	419.09	0.3144	1425.0	0.0025	0.9169	0.4415	1.9018	0.6859
05	0.9387	308.06	0.2717	1151.8	0.0070	1.1737	0.4018	2.4213	0.7528
06	0.9399	479.31	0.3218	1732.9	0.0054	1.2514	0.3596	2.4786	0.7902
07	0.9649	275.19	0.2047	500.45	0.0042	0.7443	0.5015	1.5474	0.8372
08	0.9613	1.2577	0.2590	846.35	0.0034	0.8158	0.4843	1.6902	0.8451
09	0.9588	424.38	0.2705	1010.2	0.0031	0.8869	0.4379	1.7615	0.7917
10	0.9607	476.05	0.2789	1086.0	0.0025	0.8624	0.4478	1.7300	0.7923

Table 2 continued../

House	INT	NS	FD	GS	C	PDE	Re E	M D	C C
11	0.9704	369.86	0.2790	614.95	0.0031	0.6751	0.5401	1.4627	0.8337
12	0.9610	164.03	0.5410	322.67	0.0060	0.7474	0.5047	154.86	0.7942
13	0.9456	104.19	0.4088	268.70	0.0111	0.9132	0.4251	1.8115	0.8033
14	0.9378	309.29	0.5478	1385.8	0.0058	1.2687	0.3036	2.5625	0.8007
15	0.9534	208.53	0.4207	549.65	0.0077	0.8934	0.4477	1.7993	0.7638
16	0.9490	329.20	0.5258	950.78	0.0039	1.0142	0.4145	2.0111	0.7594
17	0.9472	232.36	0.4502	737.01	0.0047	1.0380	0.3603	1.9773	0.7586
18	0.9549	377.59	0.5580	1207.0	0.0030	0.9001	0.4482	1.8677	0.7281
19	0.9382	320.12	0.5327	865.75	0.0041	0.9645	0.3974	1.9163	0.7485
Mean	0.9509	287.50	0.3478	934.10	0.0047	0.9506	0.4264	1.9198	0.7746

6.3 Graph analysis:El Ateuf sample

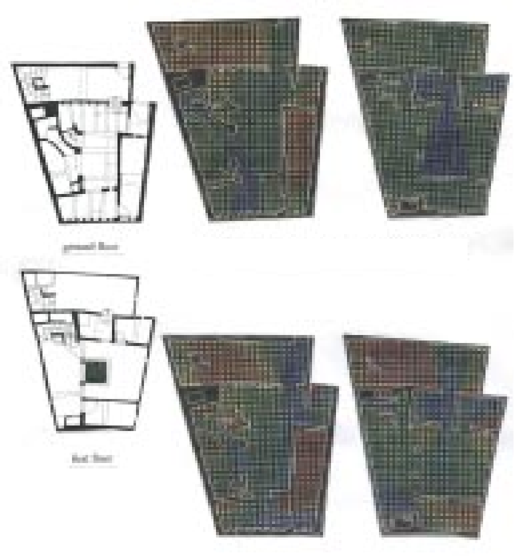
In what follows we consider the configurational characteristics of the spaces in El Ateuf traditional houses. We construct the visibility graph and Figures [13-14] show the pattern of Clustering coefficient and Point depth entropy values produced for the interior spaces of House 4. To create the figures we used a 0.2 grid of vertices covering all accessible areas in the house. Concerning the whole El Ateuf sample, Table 3 shows results that can help to better understand these houses. For instance when we look at the key global properties [Point depth entropy] or at the local properties [Clustering coefficient] some interesting points ought to be discussed.



Figures 11 and 12: Point depth entropy and clustering coefficient for house 1-Ksar of Beni Isguen

The global property Point depth entropy indicates that the houses tend to be on the higher side of the total mean [when compared to whole M’zab sample]. The values range from 0.8532 for House 10 to 1.1490 for House 6. Taking into account that the Ksar was the first to be implemented in the valley around one thousand years ago, what does this general feature mean to the results? Being on the higher side of the mean implies that the spatial configuration of the houses shows a relative difficulty in moving around the houses, thus clustering most of the spaces. The global property measure shows that 25% of the houses are on the lower scale of the range while the case of Beni Isguen [constructed around 1347] presents 42%. Can we relate this figure to the evolution of the society or to topography? All the Ksours present the same morphological features. If we look back to the results, Houses 1, 7, and 10 inclusive turn out to have low values, which means low disorder that is to say they are easily accessible in terms of permeability as well as of visibility fields. House 10 turns out to have the lowest value, 0.85, which means that it is open to visual fields from the interior, whereas, House 6 has the highest value 1.14, thus the visibility model is minimised within the house.

Concerning the local property or Clustering coefficient measure, the results also show that the most social spaces within the houses offer multidirectional fields of view and therefore low Clustering coefficient values [Figure 14]. On the other hand, the most private spaces are highly clustered which means high values corresponding in the visibility graph to the colours ranging from yellow to magenta. For instance House 8 turns to have the lowest Clustering coefficient of all with a value of 0.7092, thus, offering a wide range of field views when moving around the house. On the other hand, House 24 tends to minimise the spectrum of the field views inside the house with a value of 0.7902. Again, The analysis we have made has not considered the relation of the houses to their context. Taking into account of



Figures 13 and 14: Point depth entropy and clustering coefficient for house 4-Ksar of El Ateuf

the fact that the external envelope of the houses in El Ateuf has blank walls with few small openings and this will not raise questions with respect to visibility relations between inside and outside.

Table 3: Visibility graph of El Ateuf sample

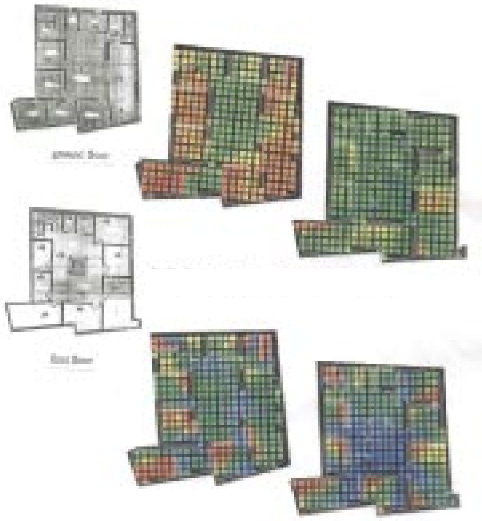
House	INT	NS	FD	GS	C	PDE	Re E	M D	C C
01	0.9572	364.13	0.2819	1110.6	0.0032	0.8732	0.4637	1.8394	0.7760
02	0.9552	407.91	0.2883	1288.5	0.0026	0.9008	0.4499	1.8720	0.7717
03	0.9563	560.96	0.3254	1658.6	0.0021	0.9501	0.4126	1.9003	0.7902
04	0.9448	265.21	0.4720	957.50	0.0038	1.0784	0.3575	2.0857	0.7777
05	0.9440	211.65	0.4592	788.41	0.0061	1.0231	0.3894	2.0824	0.7302
06	0.9421	325.26	0.5369	1438.9	0.0036	1.1490	0.3388	2.2796	0.7425
07	0.9538	217.84	0.4283	567.16	0.0049	0.8874	0.4388	1.7727	0.7603
08	0.9452	176.50	0.4103	668.00	0.0062	0.9618	0.4235	1.9987	0.7092
09	0.9411	174.27	0.4248	796.21	0.0063	1.0368	0.3919	2.1494	0.7253
10	0.9584	266.12	0.4255	602.94	0.0041	0.8532	0.4519	1.6784	0.7553
11	0.9528	398.57	0.5625	1258.7	0.0028	0.9885	0.3921	1.9377	0.7491
12	0.9546	307.51	0.4973	922.36	0.0037	0.9037	0.4434	1.8571	0.7714
Mean	0.9504	306.32	0.4260	1004.8	0.0041	0.9671	0.4127	1.9544	0.7551

6.4 Graph analysis: Melika sample

We construct the visibility graph and Figures [15-16] show the pattern of Clustering coefficient and Point depth entropy values produced for the interior spaces of House 14. To create the figures we used the same grid as in the other Ksours -0.2.

Concerning the Melika sample, Table 4 also shows some interesting results. For instance when we look at the key global property [Point depth entropy] the results show that the values range from 0.7355 for house 06 to 1.0504 for House 1. 36% of the houses lie on the lower scale of the range, 14% on the highest, and the remaining 50% are on the medium range. Again, the highest values indicate that it is hard to move around the interior spaces and low values correspond to an easy movement to a certain depth within the houses in terms of accessibility and visual fields.

As far as the Clustering coefficient measure is concerned, the results also show that the bedrooms are highly clustered whereas the Wast Eddar and the Ikoumar offer multidirectional fields of view and therefore low Clustering coefficient values [For example see House 14 Clustering and Point depth entropy graphs]. Figure 16 shows the pattern of this measure produced for the interior spaces of House 14 in Melika. As for the whole sample, Table 4 shows that House 1 turns to have the lowest Clustering coefficient of all with a value of 0.7292, thus offering a wide range of field views when moving around the house. On the other hand, House 11 tends to minimise the spectrum of the field views inside the house with a value of 0.8172. After applying the visibility graph analysis tool to the houses of Ghardaia, Beni Isguen, El Ateuf, and Melika a clear consistent pattern starts to emerge which indicates a dichotomy between 'b', 'c' and 'd' type spaces and 'a' type spaces: the first ones being accessible, open to visual fields and the second ones being enclosed and thus restricting the visibility and permeability.



Figures 15 and 16: Point depth entropy and clustering coefficient for house 14-Ksar of Melika

Table 4: Visibility graph of Melika sample.

House	INT	NS	FD	GS	C	PDE	Re E	M D	C C
1	0.9452	280.56	0.2355	753.55	0.0060	1.0504	0.4267	2.1342	0.7292
2	0.9422	111.98	0.3162	382.98	0.0098	0.9731	0.4063	1.9434	0.7941
3	0.9559	273.76	0.4935	845.45	0.0037	0.8502	0.4717	1.7955	0.7335
4	0.9406	89.241	0.3018	329.16	0.0112	0.9093	0.4567	1.9187	0.7492
5	0.9445	218.04	0.4489	855.45	0.0052	1.0240	0.3890	2.0652	0.7425
6	0.9583	189.68	0.3662	397.02	0.0066	0.7355	0.5344	1.6440	0.7817
7	0.9503	340.31	0.5837	1208.0	0.0033	0.9895	0.4047	1.9810	0.7529
8	0.9402	88.038	0.2822	296.13	0.0117	0.9689	0.4116	1.9453	0.7493
9	0.9572	556.46	0.4209	1596.6	0.0025	0.9573	0.4044	1.8550	0.7733
10	0.9585	424.18	0.5901	1150.6	0.0025	0.8411	0.4815	1.7856	0.7538
11	0.9444	129.83	0.3307	368.79	0.0091	0.9344	0.4345	1.9250	0.8172
12	0.9469	129.41	0.3143	336.04	0.0098	0.8990	0.4478	1.8329	0.8026
13	0.9585	375.97	0.5578	982.53	0.0029	0.8248	0.4858	1.7559	0.7300
14	0.9362	64.609	0.2546	272.50	0.0165	0.9403	0.4443	2.0056	0.7365
Mean	0.9484	233.71	0.3926	698.20	0.0072	0.9212	0.4428	1.8990	0.7604

6.5 Graph analysis: Bounoura sample

Concerning the Bounoura sample, Table 5 also shows that the key global property [Point depth entropy] of House 1 turns out to be a relatively high as compared to the other examples we dealt with above [value of 1.0542]. Again, the highest values indicate that it is hard to move around the interior spaces and low values correspond to an easy movement to a certain depth within the houses in terms of visual fields.

As far as the Clustering coefficient measure is concerned, the results also show that the rooms and the Tisifri are clustered whereas social spaces present low Clustering coefficient values. Table 5 shows that House 1 turns out to have a Clustering coefficient with a value of 0.7184, thus, offering a wide range of field views when moving around the house.

Table 05: Visibility graph of Bounoura sample

House	INT	NS	FD	GS	C	PDE	Re E	M D	C C
1	0.9494	490.18	0.3377	1940.9	0.0022	1.0542	0.3784	2.1098	0.7184

7. **Discussion**

Using the visibility graph we can form a new approach for the investigation of configurational relationships. The measurement of local and global characteristics of the graph for each vertex or for the houses as a whole is important to describe a spatial configuration with reference to visibility and accessibility.

The earlier description pointed to the distinctive features of the M'zabite house, in that, it is highly introverted, tree like configuration, with rooms distributed around an internal courtyard, on two floors. This combined with a division between male and female spaces. The results also showed the presence of a strong spatial genotype [i.e. in the relative degree of integration of Wast Eddar, the Ikoumar, and the Tigharghart]. The visibility mapping done on this same sample enhances the previous findings and shows that these spaces seem to be consistently placed where they can command multidirectional views whereas the other spaces [i.e. the Tisifri and other interchangeable rooms] are highly enclosed and deliberately restrict visibility and permeability. The visibility graph analysis also, shows that the visibility values [see Tables 1-5] are closely related to specific space arrangements :

- The global property presents low values for the most integrated spaces [the Wast Eddar, the Ikoumar and the Tigharghart] in the M'zab house and high values for the enclosed ones [dead-end rooms].

- The local property presents values which tend to be low at junctions and corners and as expected high values within the spatial genotypes of M'zabite houses. The geometry of Mzabite houses [see plans of the houses Figures 17-49] tends to be irregular in shape which helps to create many junctions and turning points within the spatial structure, leading to a loss of visual fields and thus clustering most of the spaces.

At first impression, these values reflect in terms of spatial configuration that the highly connected spaces ['b', 'c', and 'd' space types which refer to the Wast Eddar, the Ikoumar, and to a less extent the Tigharghart] are powerful spatial genotypes in that they command access, permeability and offer wide field of views and highlight different aspects of layout vis-à-vis the dead-end spaces ['a' type space]. The first mentioned being accessible, offering multidirectional field of views and the latter being enclosed and thus restricting the visibility. This dichotomy seems to be characteristic of the M'zabite spatial arrangements.

This paper also aims to link the depth map method to Bourdieu's social theory: the Habitus. While we cannot presume quite how this should proceed, there are some clues in the social theory. What makes depth map potent as a method is that it maps the ways in which buildings operate. It maps the Habitus, the divisions and hierarchies between things, persons and practices which construct our vision of the world. Building genotypes are powerful ideological constructs which frame our everyday lives. The spatial division of our world become a vision of our world. The building we inhabit, our habitat, our spatial habits, all reproduce our social world. Bourdieu's theory of the Habitus suggests that the built environment constructs the *real* as spatial ideology.

In this paper we have presented a new approach to the application of visual graph analysis in traditional houses. We have constructed a graph and we have made the system [houses] to accept a new set of analytic tools. This allows us to discuss any measurement of the graph in terms of its spatial meaning. The Clustering coefficient demonstrates a local measure on the graph, whereas the Point depth entropy demonstrates a global measure of the graph. The findings show that the visibility graph properties are closely related to space use and movement within the houses. We have also shown that the results come up with a consistent pattern –the private spaces are highly clustered and the social spaces offer multidirectional fields of view within the houses [See graphs produced for the randomly chosen set of Houses- 1-2, 4, 9, 11 from the Ksar of Ghardaia, House 1 from the Ksar of Beni Isguen, House 4 from the Ksar of El Ateuf, and House 14 from the Ksar of Melika].

Concerning the global property [point depth entropy], Depth map colours values using a spectral range from indigo for low values through blue, cyan, green yellow, orange red, to magenta for high values. And as mentioned earlier, this value indicates how low disorder-easy/high disorder-hard, it is to move around a house [accessibility]. The results show that the main spatial genotypes [the Wast Eddar and the Ikoumar] tend to have low values with continuous lines [mainly turning to the green], on the other hand the rooms tend to have colours turning to red and magenta. Owing to the fact that these houses are small with partitions to structure the space without disturbing too much its continuity, the low values are within the Wast Eddar that spreads to the sides offering views to the smaller rooms, and also within the Ikoumar on the first floor performing the same attributes.

As far as the local property is concerned, the clustering coefficient [visibility], the results also show that low values happen to be at junctions [corners] and involve loss of part of the visible area. On the other hand the clustering coefficient is high [The Wast Eddar, the Tigharghart, and the Ikoumar] and moving from those locations in any direction will not cause any great loss of visual information. The clustering coefficient is potentially related to the decision making process in way-finding and certainly marks out key decision points within complex configurations which is why it is important to use this tool in future design and why not in housing design.

El Ateuf being the oldest, Beni Isguen is a sacred site, Ghardaia is the largest, Bounoura is built on a rock overhanging the river bed, so can the visibility mapping be related to the history of the Ksours ? The Ksours were built between the 11th and 14th century and at a cross settlement scale the results show that houses in El Ateuf tend to be on the medium range values [see Table 1-5], noting that El Ateuf was the first settlement to be implemented in the M'zab Valley. On the other hand, houses from the ksar of Beni Isguen tend to present the extreme minimum and maximum values of all [this includes the measures of Integration, Point depth entropy, mean depth and Clustering coefficient] followed by houses from the Ksar of Ghardaia and to some extent by those from the Ksar of Melika.

The immediate context of the houses has not been considered in the analysis, as the external envelope of the houses in the five Ksours, being highly introverted, has blank walls with few small openings and this will not raise questions with respect to visibility relations between inside and outside the houses under investigation. Also, we mentioned that the settlements vary in form and size. Can this be related to the topography of the Ksours? The topography seems to be similar for all Ksours in that they are deployed on high ground. Also, the layout of the houses tends to be similar in all cases with room size and shape presenting almost the same features. Visual inspection of the house plans both within or between the Ksours does not reveal any variation in room use. The M'zabite house seems to present strongly labelled spaces configured according to a male and female spatial division. Bearing in mind that the seventy houses present the same morphological features, it becomes difficult to bring a reasonable explanation to these differences.

As a speculation, one can hardly recognise any significant differences in the Mzab houses in terms of house size and room-type, location of particular spaces within the house, the usage and use of the different spaces, orientation, fitting/furniture, etc.; that can help to build a clear vision of how these spaces might be arranged. However, we can argue that it is possible to reconstruct from these measurements, the spatial meaning of the M'zabite domestic spaces.

We must recognise that this research work is still experimental, but, as stressed by Hanson. J. it might turn out to have interesting practical applications. In this sense she said [12]:

"*For example, in group residential homes for people with Alzheimer's disease or for those suffering from dementia, it is believed that some forms of wandering behaviours may be therapeutic in that they relieve the boredom and stress of living in a highly controlled, enclosed environment but other forms of confused wandering seem highly* *stressful and may even exacerbate people's symptoms. It is therefore important to know which kind of space provide a positive stimulus to residents and which are deleterious*".

Further work needs to be done in order to gain comprehensive results from this new tool of analysis. Although the characterisation of space in this way is interesting, much work on the application of the analysis is still required. Most importantly we need to develop a more systematic method to discover new characterisations for architectural types, and to classify their configurations.

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Annexe:

The following are the main spaces that constitute the M'zabite traditional house. The numbering that precedes each constituent space will be used in the description of the house drawings that will be shown in Figures [17-49].

X: Exterior
1: *Skifa, Taskift* or chicane.
2: Intermediate space.
3: *Tissounane* or stairs.
4: *Houdjrat* or ground floor male reception room.
5: *Dahlis* or cellar.
6: *Wast eddar, Ammas N'Tadart*, or centre of the house.
7: *Tisifri* or women's living room.
8: *Inayen* or kitchen.

9: *Ajmir* or toilets.

10: *Lamghassal* or traditional bathroom.

11: *Tazeka N'El Aoulet* or storage room.

12: *Ikoumar* or arched portico.

13: *Tazeka* or room.

14: *Tigharghart* or upper courtyard.

15: *Aali* or first-floor male reception room.

16: *Tazadit* or animal room.

17: *Stah* or terrace.