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Contribution of Morphometrics in the Study and Conservation of an Urban Heritage

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Abstract

The ksar of Ouargla is among the most beautiful Saharan ksour built for more than 6 centuries. It is classified in 1996 as national heritage, and was also registered in 2008 as a protected sector. The objective of this research is to make a morphometric study by using the software of Matlab and Morphic to analyze the morphogenesis of the urban form of this ksar (the traditional urban fabric) and to try thereafter to reconstitute the destroyed part in the neighborhood of Benni Sissine by the same logic of construction. The study will be carried out in three steps; the first consists of choosing the corpus of study, starting with the fabric of ksar, then the neighborhood of Beni Sissine and, finally the islets. The second step is the coding of 2D images in gray levels with values between 0 (black) and 255 (white), using Photoshop software, and the third step is the study of the genesis of the form through the analysis of these images by the Matlab software. The results of this analysis will be used to propose a reconstruction of the destroyed part of Beni Sissine based on the same logic of the construction of the initial form.

Keywords: Ksar of Ouargla, , Matlab, Morphic, Morphometrics, Photoshop, Saharan heritage

INTRODUCTION

Heritage is a real potential for development, and a means of satisfying a number of artistic, aesthetic and even leisure needs, it is therefore a source of several existence values (HANAFI et al., 2021). It remains a generic and ethical notion that has moved from individual to collective value, from sectoral to global (HAMMOUDI, 2014).

Urban heritage is the memory of a city, and the overall landscape it constitutes shows the typical scene of a city in a certain historical period (WANG, 2011). When we want to define "urban heritage", what comes to mind for most urban planners and managers is usually "monuments". This conception often excludes historic residential areas and historic city centers which also represent urban heritage (STEINBERG, 1996). It is part of the history and memory of a city, and history would be discontinuous without it (WANG, 2011).

The role of heritage goes beyond the testimony and marking of history and being a landmark in time and space. Heritage is a source of inspiration either for architecture, art or urban planning (HANAFI et al., 2021).

The urban heritage in Algeria represents an extremely varied reality. The ancient "Medinas" of the cities of the agricultural plains or the coastal strip, the colonial cities, and the long chain of ksour that stretches from southern Morocco to southern Tunisia and which presents an undeniably rich urban heritage (COTE, 2005).

The Ksourian architecture represents a heritage of undeniable wealth. The Ksar means palace, it represents the human settlement of the Sahara with a rural tendency; it is a fortified complex built for generally defensive reasons (on rocky and high grounds), occupying strategic places at the crossroads of the caravan routes and forming a long chain of ksour which spreads out from the south of Morocco to the south of Tunisia (COTE, 2005). They are the testimony of an urban civilization with multiple cultural stratifications.

Most of the Ksourian heritage, which constitutes an important component of the Algerian urban heritage, is nowadays facing serious threats. The protection of the heritage is a matter of morality and respect for the people who have already passed and for the dignity of the human person (HANAFI et al., 2021). Therefore the reconstruction and preservation of heritage have become a necessity. Not only for reasons of nostalgia, but as a need for know-how expresses the ability of

people to adapt to the conditions of their harshest natural environment, leaving an architectural lesson for lovers of the past, as a need for aesthetics when returning to the achievements of a very flourishing era in art and architecture, and need for historical knowledge to know history through an architectural stamp.

Morphometrics is a method of analysis used to bring out the intrinsic properties of the form and to identify its structure (KACHA, 2010)

Geometric Morphometrics includes the study and analysis of the geometry of a structure, whether biological or not. It is derived from traditional Morphometrics and, based on a statistical approach (CARAYON, 2018; VUILLIEN et al., 2017). Geometric Morphometric methods, often based on Cartesian coordinates of landmarks that retain all geometric information in the data throughout an analysis (SLICE, 2007) .

It is a scientific method, numerical and independent of human perception, used to study and analyze the shape of a structure, regardless of its origin (SUISSI, 2017; BELDJILALI & BOUGARA, 2019). According to BEN SACI, Morphometrics is the operation of measuring spatial form. It institutes a quantitative approach and a numerical characterization of the forms which are based on the measurement principle (BEN SACI, 2000).

The so-called traditional Morphometrics is based on measurements of distances between more or less homologous points on organisms or part of them, following the disadvantages that it presents this method, it was developed geometric Morphometrics towards the end of the 70s, by the statisticians Kendall and Bookstein, this new method considers the shape independently of the size as a geometric conformation (METAIRIE, 2014).

According to FUCHS, it should allow the study of forms to be objectified, to classify and arrange forms, to measure the distances between forms and classes of forms, and to understand the intrinsic properties of forms. It should make it possible to apprehend the forms produced by the city, to compare them, and to classify them in an objective and automatic way (FUCHS, 2001).

Morphometrics is based on the analysis of variations in shape and their variation with other variables (BOOKSTEIN, 1991). This method allows automatically measuring, characterizing and classifying shapes according to their frequency representations and with the abstraction of any appearance and perception effects. (SOUISSI, 2017).

The description of the shape in this approach is in the frequency domain. That is to say, measuring the shape is passed from spatial information to frequency information. The frequency analysis consists in decomposing the shape and projecting it in the frequency domain, or each shape is a "Morphic stratum" whose frequency axis is a superposition of several strata. According to (SUISSI, 2017) It is a hierarchical decomposition that is done from low frequencies (fundamental strata of Morphic information) to high frequencies (complementary strata of Morphic information). The low frequencies are responsible for the appearance of the complete form while the high frequencies are responsible for the appearance of the details.

Computer-assisted geometric Morphometrics is based on the acquisition, processing, and analysis of reference points described along the "X, Y, Z" axes and observed on the surface of objects whose spatial configurations are to be studied (CARAYON, 2018).

Advanced modeling and data analysis software and computerized visualization have advanced the process of historical and critical knowledge. This method has already given interesting results in the case study of the Medina of Tunis (BEN SASSI & ZAABAR, 2012).

Our work consists in making a Morphometric study in order to bring out the morphogenesis of this Ksourian fabric and to try thereafter to make the reconstitution of the destroyed part of the Ksar of Ouargla.

CASE STUDY

Known as Ouardjelane, or Ouarglène; The origin of the name of the city of Ouargla goes back to the name of the first population, but for 3 centuries the name commonly used to refer to this city is Ouargla (GHERRAZ, 2013). The ksar is undoubtedly, the most rooted in the history of the Sahara, an important national heritage given its size, complexity, originality, urban organization and historical interest (KADRI et al., 2015). This ksar presents the first core of the current city after the fall of the city of Sedrata and the destruction of its site. Its location is well chosen, a favorable site to create a new human settlement, at the crossroads of caravan streets and a site very rich in water resources. It is surrounded by an enclosure pierced by 7 gates, each of which opened onto the nearest city street, but (DELHEURE, 1988) has cited only 3 gates.

According to (COTE, 2005) "The old Ksar of Ouargla is presented as a compact circular entity with a high density, the fabric is strongly structured and marked by the landmark elements like the mosque".

The ksar is composed of three ethnic parts, the urban organization of each of the three parts reflects a social organization well hierarchical whose broad outlines are summarized in the following figure: Each ethnic group occupying a neighborhood that is organized into several fractions that are composed of sub-neighborhoods, organized around the structuring spaces called place of Djemaâ (Figure 1).

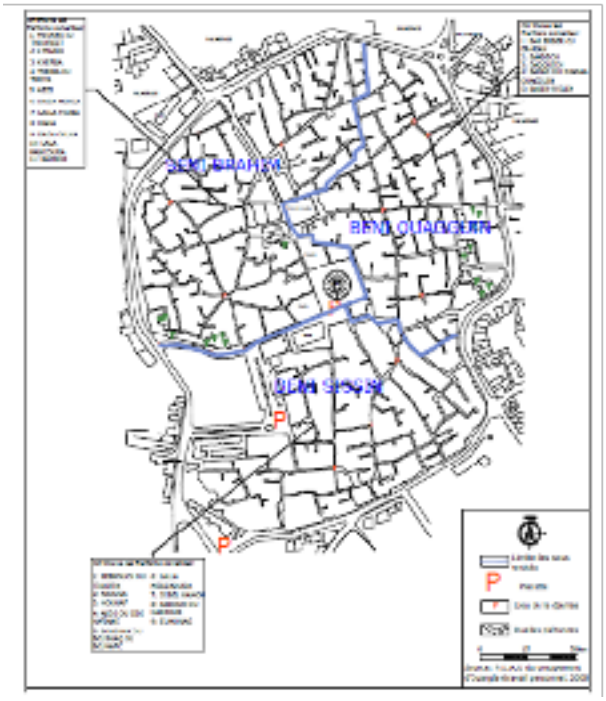


Figure 1: The urban structure of the Ksar of Ouargla (GHERRAZ, 2013)

The choice of this study focused on the Ksar of Ouargla for its formal and spatial particularity, a well-structured urban fabric characterized by a tight grid that reflects the urbanization of the Arab city par excellence. But unfortunately this structure was affected by the destruction of the year 1872 led by the French army under the order of General Lacroix whose objective was the destruction of the kasbah and the house of Bai and the realization of a breakthrough that facilitates access to the center of the ksar (from Bab Sultan in the neighborhood of Beni Sissine), This place is linked to the centre of the Ksar by a street called Rivoli (GHERRAZ, 2013).

Therefore, the present study is devoted to study the phenomena of emergence of the urban form of the Ksar. Whose purpose is to propose a reconstruction of this demolished part following the same logic of construction of Ksar through the use of Morphometrics.

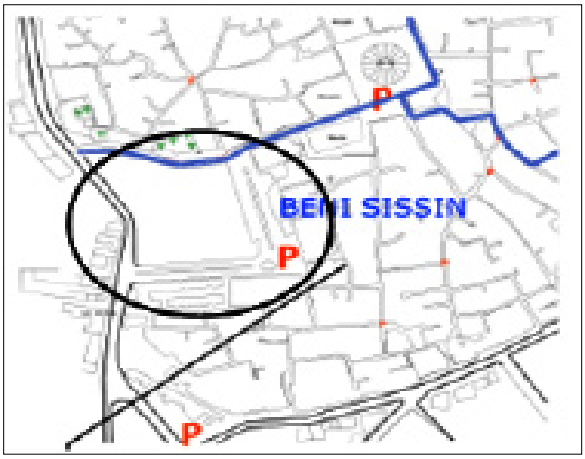


Figure 2: the demolished part in the Beni Sissine fabric

MATERIALS AND METHODS

The work consists of a morphometric study in order to bring out the morphogenesis of this Ksourian tissue and then try to reconstitute the destroyed part. This operation consists of three parts:

1- The urban fabric of the ksar and its spatial composition

2- The part of Beni Sissin as a structural autonomy of social and urban organization

3- The islands (in the Beni Sissin area) as a structural element.

After the choice of corpus of study the images of the selected urban fabrics will be treated and codified by Photoshop in image at the level of gray, after they will be analyzed by Morphic to obtain the various Morphic strata in order to know the phenomena of emergences of the urban form, after to propose a reconstruction of the demolished part according to the same principle.

The Study Corpus

-The ksourian fabric: the choice of urban fabric of ksar for the purpose of understanding the reason of formation of the complete form (Figure 3).

-The Beni Sissine neighborhood: this is the area where the demolished part is located (Figure 4).

Figure 3: the urban fabric of Ksar

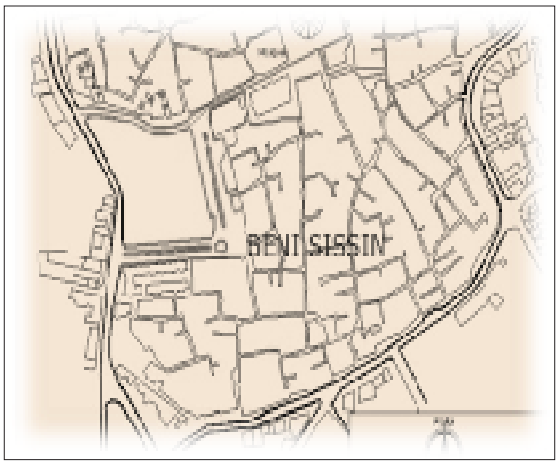


Figure 4: the urban fabric of Beni Sissine

-The islets:

-Islet n°1: this islet is located in the south-western part of the Beni Sissin neighborhood, to the south of the destroyed part (Figure 5).

Figure 5: Location of 1st islet

-Islet n°2: The islet is located in the center of the neighborhood, in contact with the market place of the ksar, but it is not in contact with the demolished part (Figure 6).

Figure 6: Situation of the 2nd islet

Islet n°3: The islet is located in the center of the neighborhood in contact with the second islet in the East (Figure 7).

Figure 7: Situation of the 3rd islet

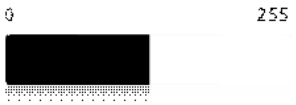
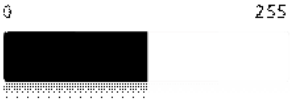
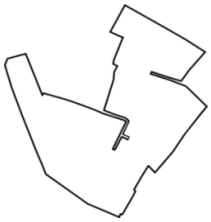
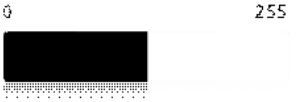
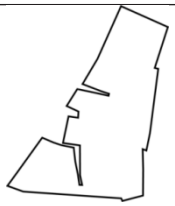
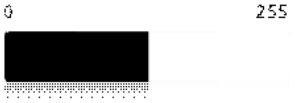
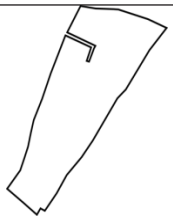
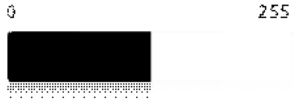
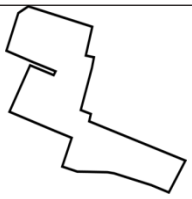
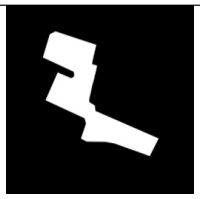
Islet n°4: The islet is located in the northern part of the neighborhood; it is in contact with the demolished part on the west side, and with the center of the ksar by the northern part (Figure 8).

Figure 8: Situation of the 4th islet

Analysis of Study Corpus

3-2-1-The coding of the images: the selected images will be treated by Photoshop, and will be codified in level of gray with values between the 0 and 255 of which the white represents the white and the black represents the vacuum. After coding, the images will be saved in TIFF format. Then, to start the frequency analysis, we must go through the MATLAB software and launch the application MORPHIQUE 3. The following table shows the images before and after the codification with the values of gray (Table 1).

Table 1: Image Coding

	Before codification	Coded image	Shade level
P1			
P2			
I1			
I2			
I3			
I4			

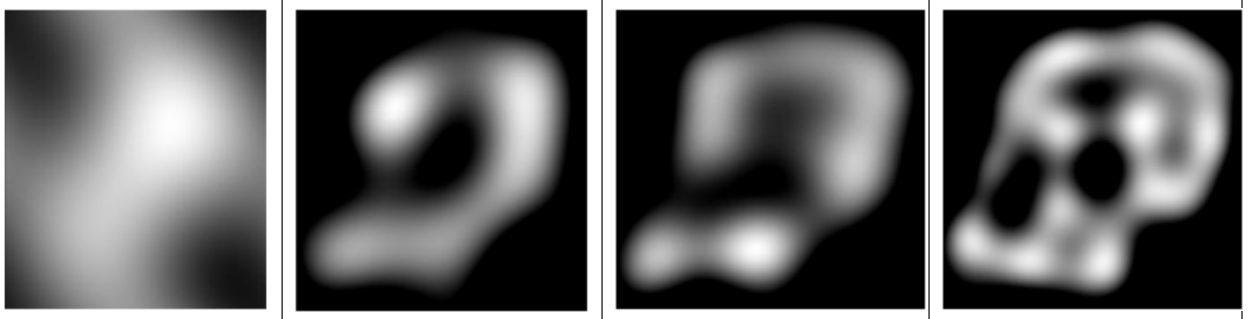
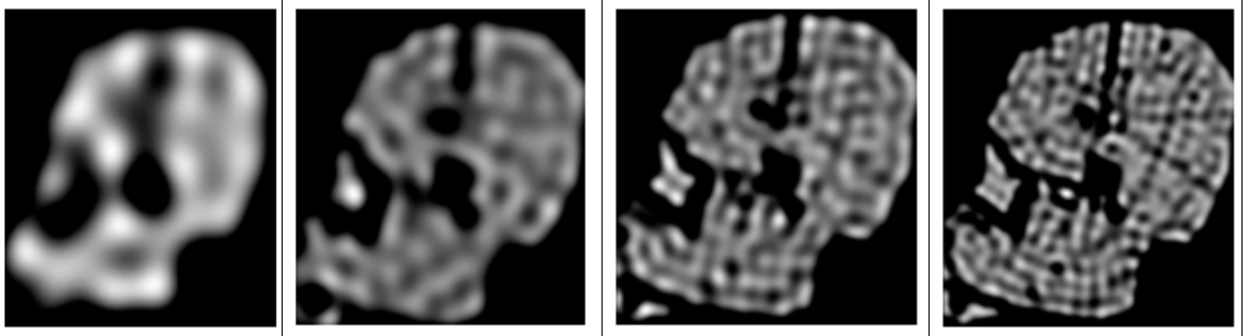
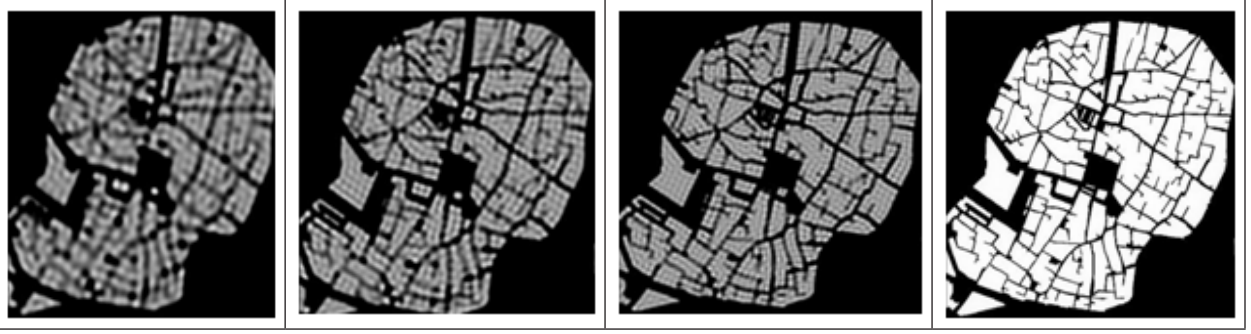
RESULTS OF THE MORPHOMETRICAL ANALYSIS

After the coding of the images, we went back to the Morphic to analyze the morphogenesis of each tissue.

The Morphogenesis of the Shape of the Ksar

The following table shows the results of Morphometrical analysis of the urban fabric of the Ksar (Table 2).

Table 2: Morphometrical analysis of the urban fabric of the ksar

Analysis of the urban fabric of the Ksar				
Low frequencies				
medium frequencies				
High frequencies				

The analysis of these results is done according to the type of frequencies, starting with the low frequencies:

Analysis of Results on Low Frequencies

The initial shape of the ksar is articulated around a central void that structures the whole urban fabric of the ksar (Figure 9), this void presents the market place, a second lateral void appears in the left part of the circular shape forming a discontinuity, and this discontinuity is on the destroyed part. The appearance of this void on this low frequency shows the important size of this part.

On the frequency 1-5, we notice the appearance of other voids in the structure of the fabric just around the central void, more exactly, three small voids and a fourth larger one. On this frequency we can see the formation of three masses around the center with the change in the shape of the central void. This frequency coincides with the formation of three autonomous urban structures with their own centers (the three ethnic parts).

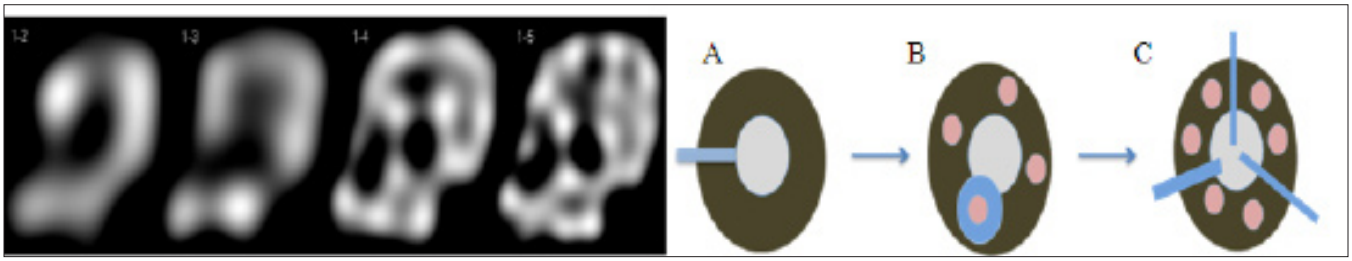


Figure 9: Low frequency results (the urban fabric of the Ksar)

Analysis of Results on Low and High Frequencies

The medium and high frequencies are the frequencies of the appearance of details. On the medium frequencies, the very clear appearance of three different fabrics. In the high frequencies, the appearance of small voids, streets and alleys that connect them until the complete formation of the final fabric (Figure 10).

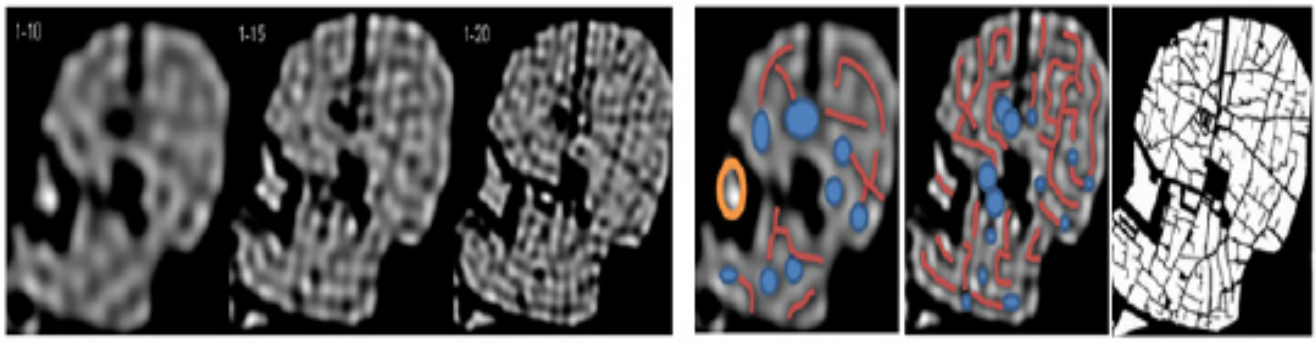
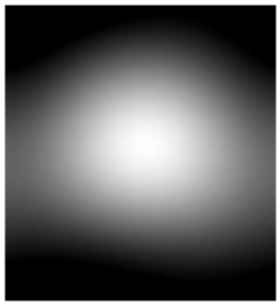
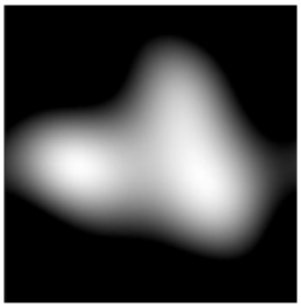
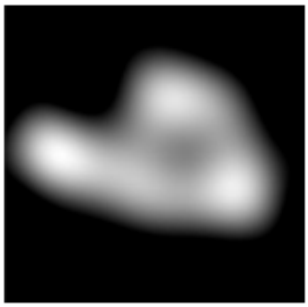
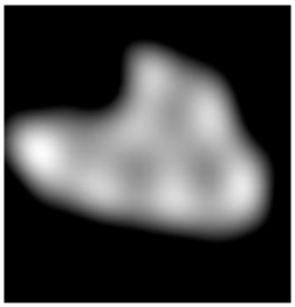


Figure 10: Results of low and high frequencies (the urban fabric of the Ksar)

The Morphogenesis of the Shape of the Beni Sissine Neighborhood

The following table shows the results of Morphometrical analysis of the urban fabric of the Beni Sissine (Table 3).

Table 3: Morphometrical analysis of the Beni Sissine neighbourhood fabric

Analysis of the urban fabric of Beni Sissine				
Low frequencies				
medium frequencies				
High frequencies				

Results of the Low Frequency Analysis

At low frequencies (Figure 11), the initial shape appears as a single entity pierced by small voids distributed along two axes.

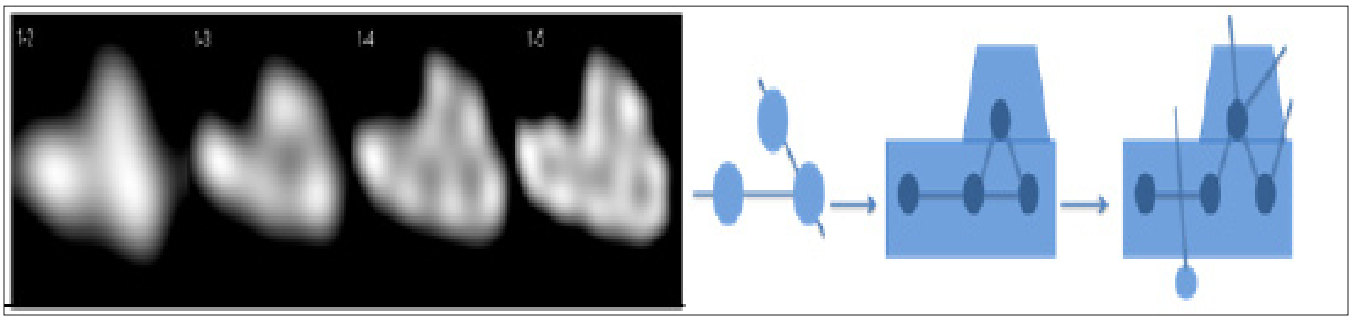


Figure 11: Low frequency results (Beni Sissine neighborhood)

Results of the Analysis on the Average and High Frequencies

The distribution of the voids was made in several directions on the medium frequencies in curved forms. On the high frequencies, we notice the clear appearance of streets, alleys and small squares (Figure 12).

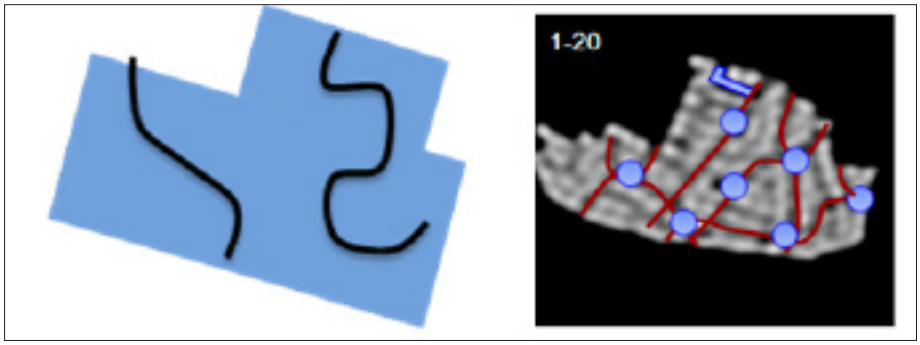


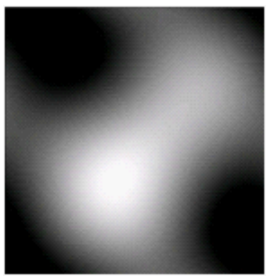
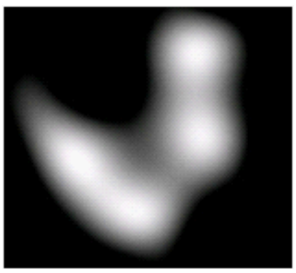
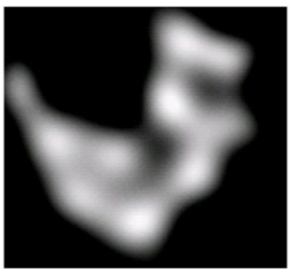
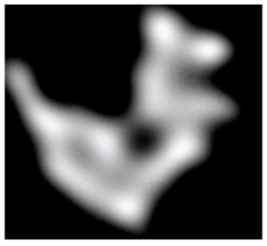
Figure 12: Results of the average and high frequencies (Beni Sissine neighborhood)

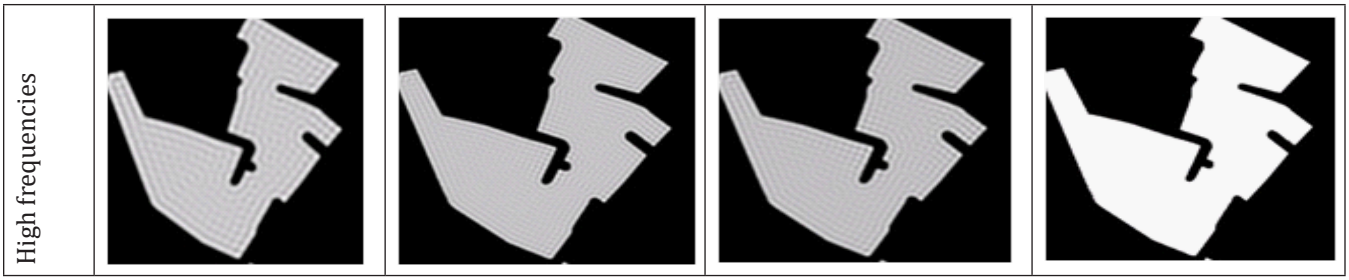
Morphogenesis of the Shape of the Islets

Islet N°1

The following table shows the results of Morphometrical analysis of the urban fabric of the 1st Islet (Table4).

Table 4: Morphometrical analysis of islet N° 1

Analysis of the urban fabric of Islet 1				
Low frequencies				
medium frequencies				



The recorded results show that at low frequencies, a single U-shaped entity is observed, with some lateral breakthroughs.

On the medium and high frequencies, we can clearly see the formation of the final shape of the island pierced by some alleys and dead ends (Figure 13)

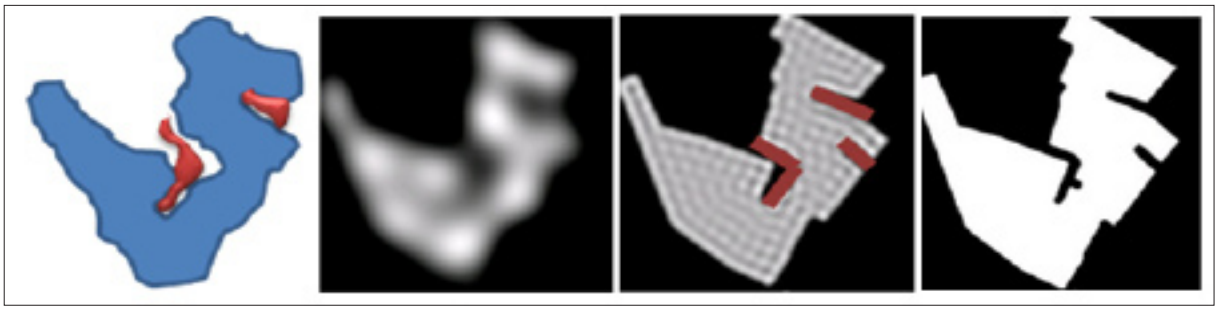


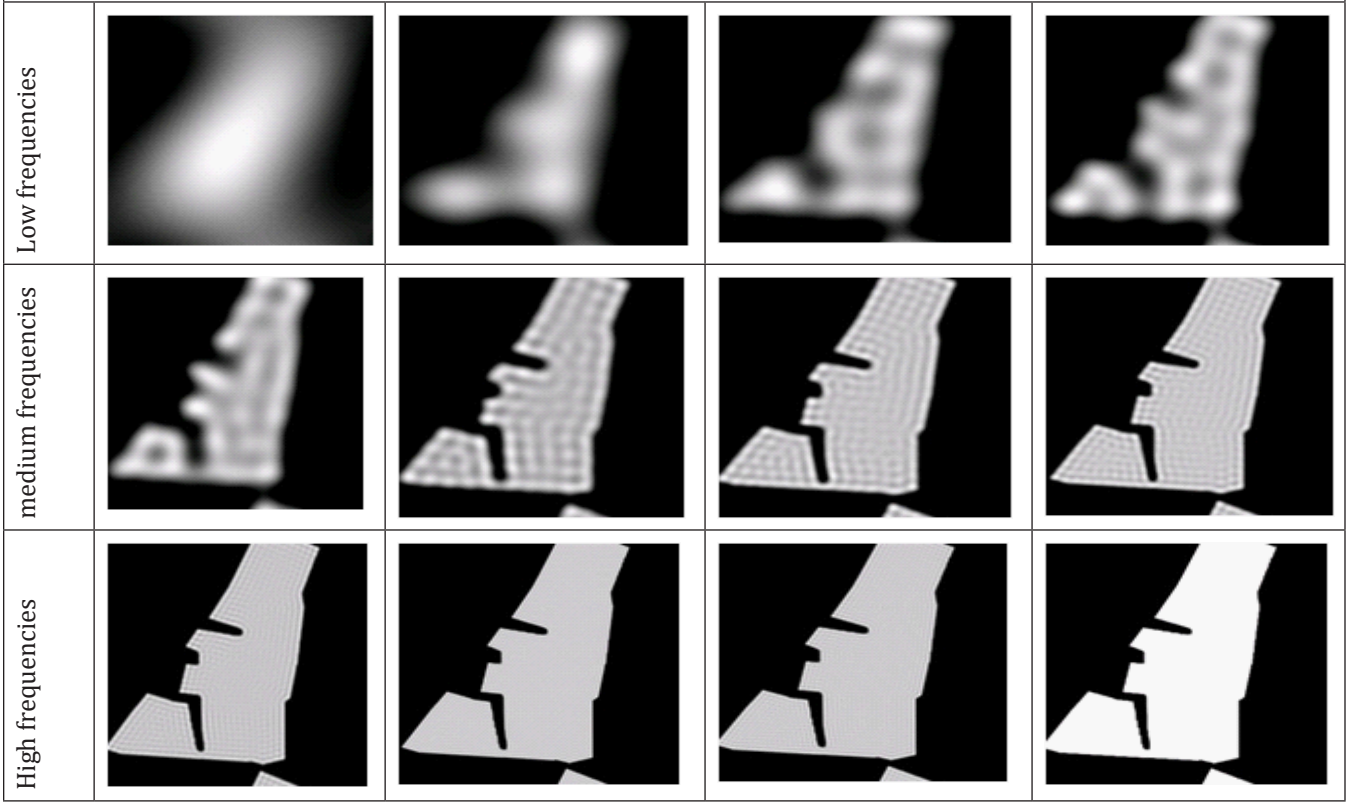
Figure 13: Low, medium and high frequency results (Islet 1)

The Second Islet

The following table shows the results of Morphometrical analysis of the urban fabric of the 2nd Islet (Table 5).

Table 5: Morphometricl analysis of islet N°2

Analysis of the urban fabric of islet n°2



Our results on the low frequencies show the appearance of an inverted L-shaped mass. On the medium frequencies, the formation of several linear voids in the western part of the islet. As for the high frequencies, the complete formation of the shape of the islet pierced by several alleys and dead ends (Figure 14).

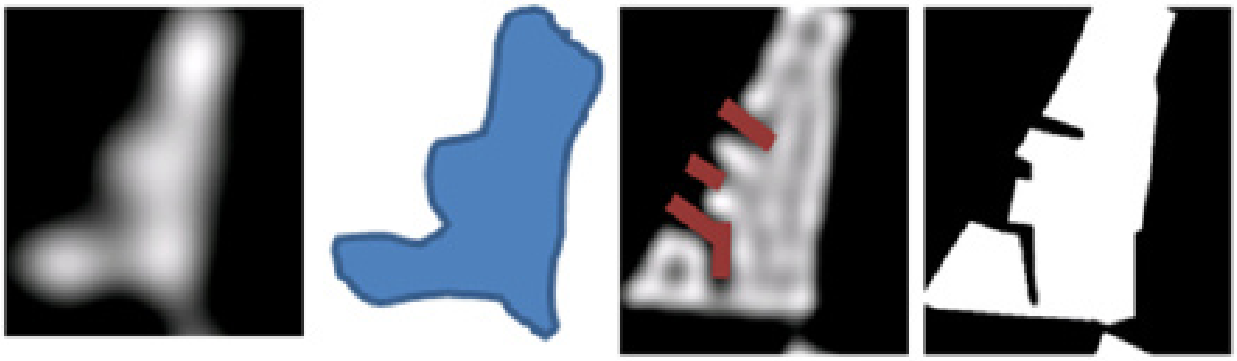
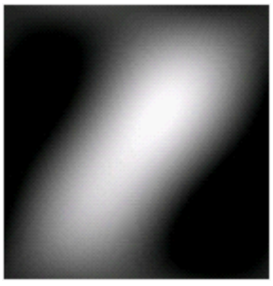
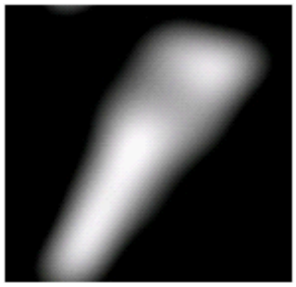
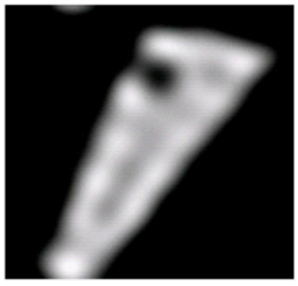
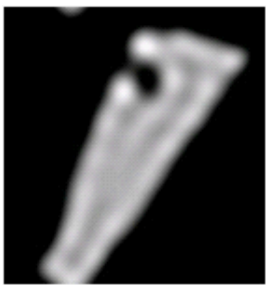
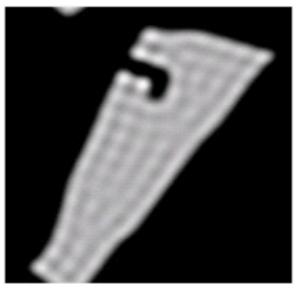


Figure 14: Low, medium and high frequency results (Islet 2)

The Islet N°3

The following table shows the results of Morphometrical analysis of the urban fabric of the 3rd Islet (Table 6).

Table 6: Morphometrical analysis of islet N°3

Analysis of the urban fabric of islet N°3				
Low frequencies				
medium frequencies				
High frequencies				

At low frequencies, we observe the formation of a linear mass, which is not uniformly distributed.

On medium frequencies, the appearance of a cavity in the upper part of the mass. On the high frequencies the complete formation of the mass (Figure 15).

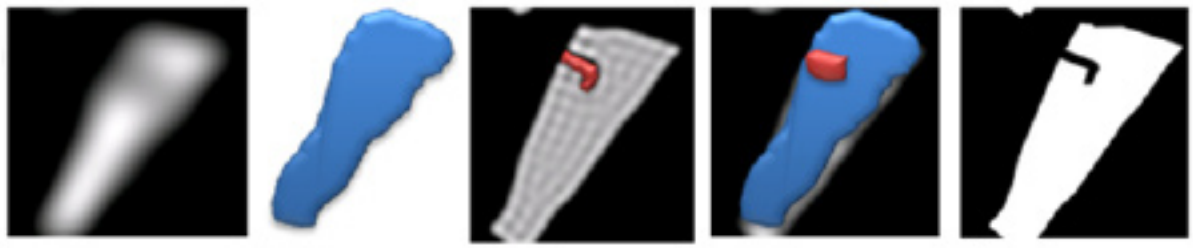
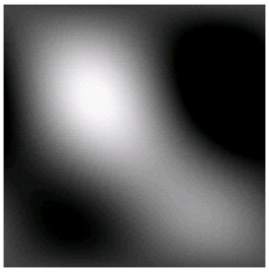
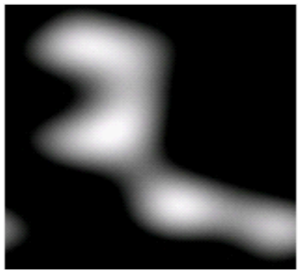
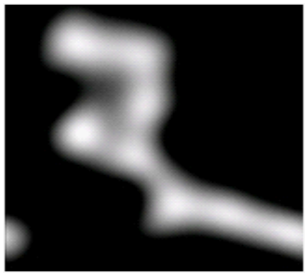
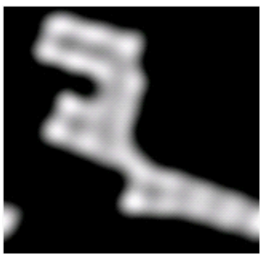
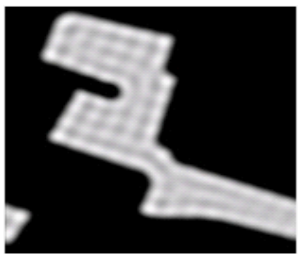
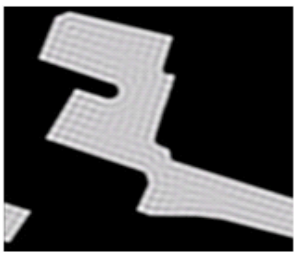
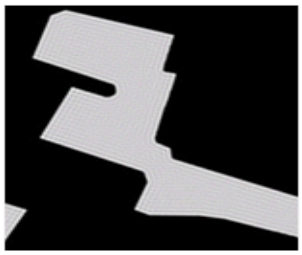
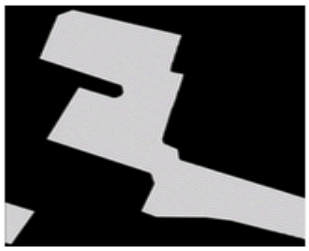


Figure 15: results of low, medium and high frequencies (Islet N°3)

The Islet N°4

The following table shows the results of Morphometrical analysis of the urban fabric of the 4th Islet (Table 7).

Table 7: Morphometrical analysis of islet N°4

Analysis of the urban fabric of islet N°4				
Low frequencies				
medium frequencies				
High frequencies				

The results show that on the low frequencies we have marked the appearance of the first mass, a linear mass pierced in the west side. On the medium and high frequencies, we recorded the complete formation of the final shape pierced by a single lane; this island has a simpler shape than the previous islands (Figure 16).

Figure 16: Low, medium and high frequency results (Islet N°4)

DISCUSSION

Classifying the Results

This step consists in sorting, classifying and grouping the samples according to the phenomena observed during the frequency analysis (Table 8).

Table 8: classifiying of results

	Phenomena (indicators)	Samples					
		P1	P2	I1	I2	I3	I4
Low frequencies	Peripheral occupancy (1-2)	X					
	Linear distribution (1-2)					X	
	Distribution on two axes, or L-shaped (1-2)		X		X		
	U-shaped distribution (1-2), (1-3)			X			X
	Concavity (1-2)	X		X	X	X	X
	Appearance of voids (1-3)	X	X	X	X	X	X
	Linear vacuum formation				X	X	
	Star development	X	X	X		X	
	concentration around the centre (1-5)	X					
	Linear evolution of the concavity			X	X	X	X
	Linear evolution of large voids	X	X	X	X	X	
	Linear expansion of the mass (1-5)			X			X
High frequencies	Formation of major axes	X	X				
	Complete training of the form	X	X	X	X	X	X
	Appearance of detail	X	X	X	X	X	X

Discussion of Classified Results

Planes P1 and P2

At low frequencies the common indicators are:

-The formation of the initial form (a compact mass);

-The appearance of voids;

-The development of mass and voids (linear or circular development) ;

At medium and high frequencies, in addition to the complete formation, and the appearance of complete detail of the form.

The Islets I1, I2, I3 and I4

At low frequencies, the repetition (in the majority or unanimity of the samples) of several indicators was recorded, in the following order:

1- Distribution on two or three axes 3/4

2- Concavity from 1-2 to 1-5 4/4

3- Appearance of large voids 4/4

4- Linear evolution of the concavity

5- Linear evolution of large voids 3/4

At medium and high frequencies, we only have the complete formation of all the islands.

Confrontation with Extrinsic Elements

The Plan of Ksar

At low frequencies, we notice the appearance of a central void in the center of the crown, this void is the central square of the Ksar, a space structuring par excellence the entire urban fabric, while at medium frequencies we notice the division of the entire mass into three parts that represent the three ethnic parts (Figures 17 and 18).

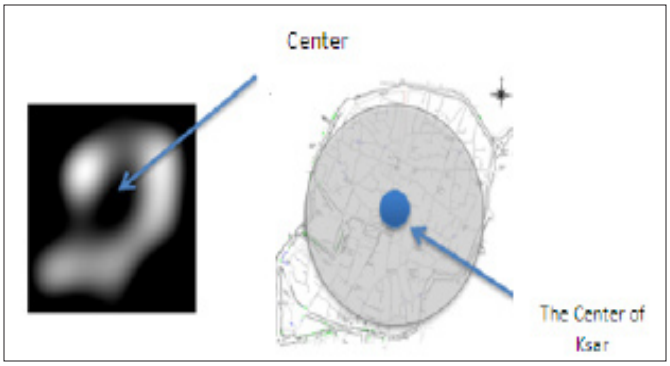


Figure 17: organization around a centre**.**

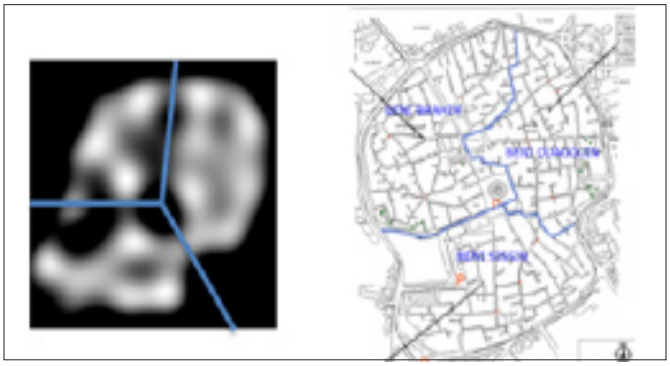


Figure 18: Distribution into 3 ethnic parts**.**

The Neighborhood of Beni Sissine

For the Beni Sissine neighborhood, no centre was noticed either at low or high frequencies. For the formation and distribution of voids at medium frequencies these voids represent the squares that exist in this area, while at high frequencies the development of voids represents the tertiary roads and the dead ends that lead to the doors of the houses (Figure 19).

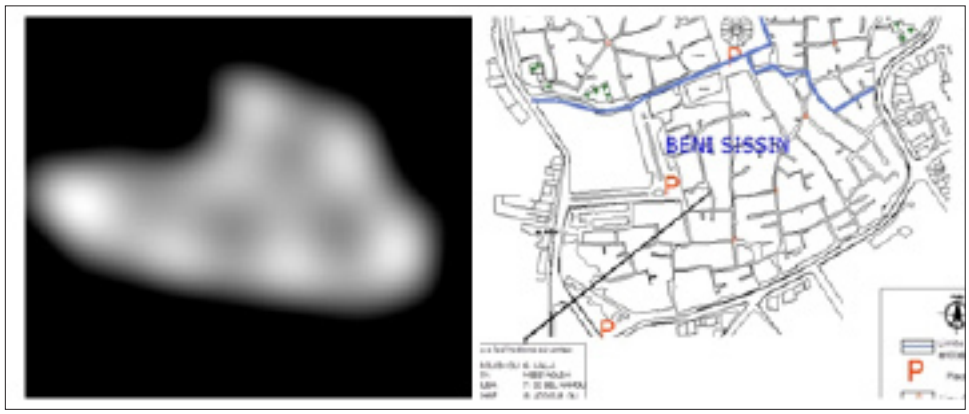


Figure 19: the first formation of the shape of the neighborhood.

The Islets

For the islands at low frequencies, we notice the appearance of the initial mass distributed on two axes for the peripheral islands, and on a single axis for the central island.

As for the high frequencies, we have recorded the appearance of the voids that represent the dead ends; generally each islet is pierced by one or two dead ends (Figure 20).

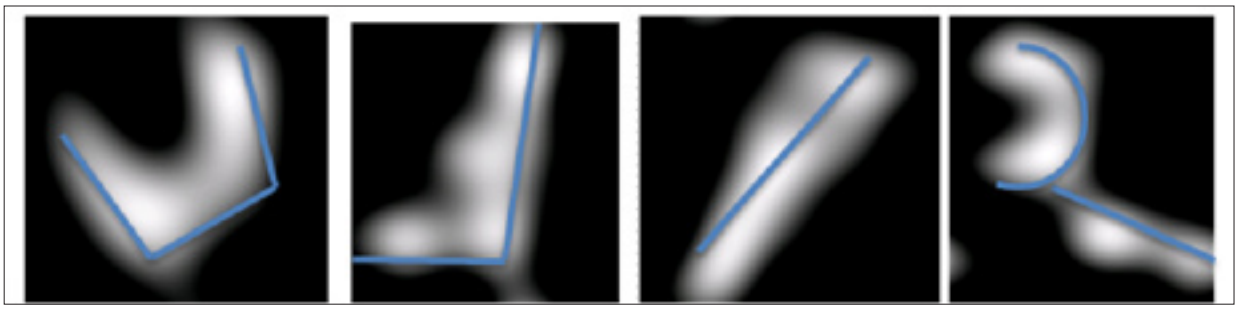


Figure 20: the first formation of the shape of the islands 1,2,3 and 4 respectively.

Proposal for the Reconstruction of the Destroyed Part

In this stage we will try to make a proposal of reconstruction for the demolished part through the results obtained from the Morphometric analysis.

From the results obtained previously the proposal of reconstruction is as follows:

- ✓ Peripheral islands with a shape that keeps the continuity with the peripheral road that surrounds the Ksar, these islands are divided into two axes.
- ✓ Central islands are distributed in a single axis
- ✓ For the large voids that represent the main roads are in continuity with the rest of the urban fabric.
- ✓ As for the dead ends, they are also in continuity with the rest of the fabric and each islet is pierced by at least one or two dead ends (Figure 21).

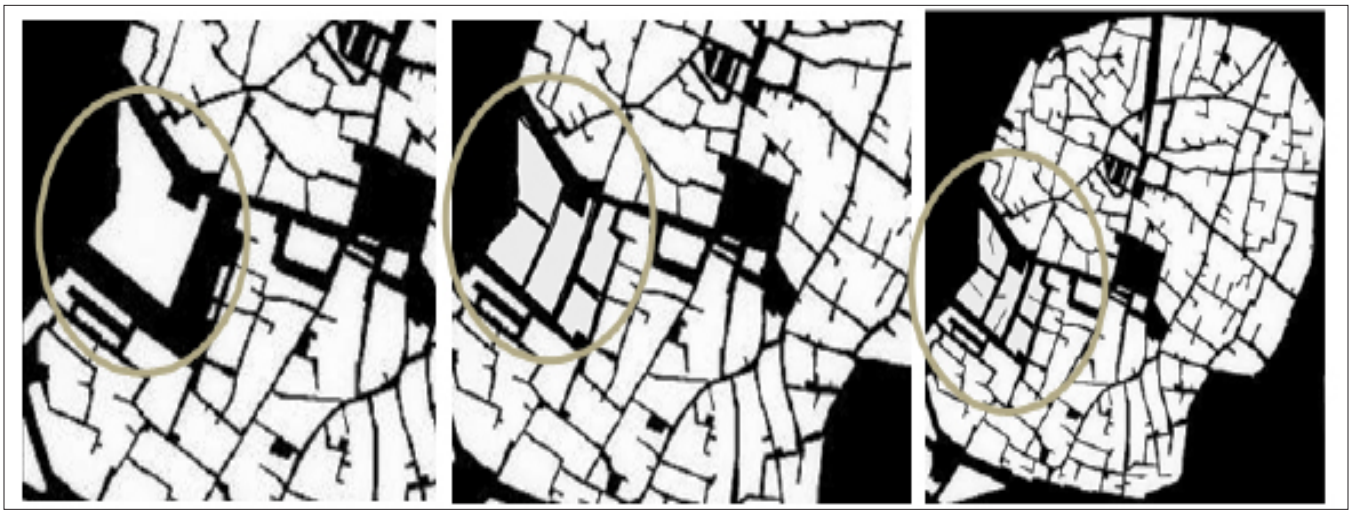


Figure 21: Proposal for the reconstruction of the demolished part

CONCLUSION

In addition to the direct contribution of this method in terms of objectivity of the analysis of forms, which is very important in architecture, Morphometry opens the field to scientific measurement in architecture, or rather to the dialogue on the working tools in particular in the field of heritage to understand the morphogenesis of the old urban fabrics.

Our study focuses on the Ksar of Ouargla because of its importance as a classified heritage. The demolished part in the district of Benni Sissine remains an island that spoils the homogeneity of the traditional fabric of this Ksar.

Through the example of the Ksar of Ouargla, we will see that delicate operations such as the reconstitution of a demolished part can be possible thanks to Morphometry, which is considered a real discovery. Finally, this work has allowed us to understand the existence of phenomena of emergence of the form or the emergence of phenomena which make the emergence of the form.

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