ANALYSIS OF PRODUCED FORM AND INNOVATION IN ARCHITECTURAL DESIGN

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Abstract. This paper is about the analysis of architectural objects; it follows and compares the form’s variation. In fact, a collection of buildings can be characterized by the morphology decomposition or the morphometric treatment. Operating method is put in place to study the possible arrangements of the basic components according to morphotic structures and predefined relations. Based on the questions about the produced form, this method promotes a creative situation; it can support and help teaching innovation in the field of architectural design.

1. Introduction

The architecture is at the same time a discipline of action and knowledge. It is about the practice of the research according to three ways: the experimental, the applied and the basic researches. Those three ways of action contribute to the construction of the architectural knowledge and cooperate at several levels in the development of an architectural science (Renier, 2002). The Primary System of Architecture PSA: specified functional, formal and architectonic, is in interaction, with the data of the External Environment EE: the general context of the architectural production (Ben Saci, 2000).
Architectural object have a great morphological diversity; it belongs to a set of forms that are containing a preliminary morphological and mold of form (Duprat, 1999). The morphological aspects of the produced objects (Duprat, 2008) are formalized to produce knowledge which can allow didactic tools for teaching architectural design. Knowing is essential to understand what is made (Dhouib, 2004); it serves to guide the innovation in future actions (Zwicky, 1966; Le Masson, 2007).

We are working on houses from North Tunisian villages known as "Andalusian", by confronting them with houses of sites depopulated from Al-Andalus, the Islamic Spain (Badrani, 2009). Many analytic approaches propose a comparison of houses: they are from Spain (Bazzana, 1992-1993; Navarro, 2005), from the Maghreb (Saadaoui, 2000) and generally from the Arabic and Islamic world. Authors were interested in introversion concept "the inner dimension" of traditional Islamic house, as well as in the architectural archetypes.
of the traditional residential structures according to the geographical region; in their classification the "Maghrebian - Andalusian" houses are absolutely with a patio (Hakim, 1986; Bianca 2000).

In spite of their merits, none of the analytical methods was interested in evaluation of the form or in its measure; none of them have led a rigorous comparative work. None of it seemed perfectly adapted to the definition of morphological properties (Badrani, 2002). Altogether, it is a question of many classic descriptive, explanatory and justificatory methods and carriers of knowledge, but who remain subjective and treat only particular cases. These methods cannot be applied in a systematic way. Indeed, a perfect method of analysis of the architectural form of "Andalusian" houses does not exist. Nevertheless, counts of methods of form measurement exist in a lot of domains, one of which is the morphometric treatment (Ben Saci, 2000). Our research is interested in the study of the variations as well as at the level of morphologic stability between specimens of the supposed homogeneous collection. Aiming for a complete and objective approach, an assessment grid was finalized and applied within the limits of the available information, we fixed operators having a reliable measurement tool for the produced form, easy to manipulate, adaptable to the analysis conditions. We assume that a morphological link exists between specimens from the same collection; we try to demonstrate this through the thematic areas and the analyzed material. We conduct an empirical collection (Duprat, 1999), initially designated by a nominal identity (objects with the same name), a corpus of specimens with a supposed morphological identity. The two identities cannot be confused, as there is no reason to expect that all objects with the same name could have the same form. It is necessary to make difference between description and analysis.

Despite many merits, archaeologists, historians and journalists approaches still referred to insufficient descriptive work, and they are not adequate to characterize the produced forms. In what follows, we present the morphological reflection and we precise objectives of the study. The collection is constituted by houses identified on traditional "Andalusian" cities in North Tunisia and by houses of depopulated Islamic sites of Spain. We were led to the identification and explanation of significant parameters characterizing the form of objects in question.

2. Analysis of architectural forms, theory and applications

This research concerns analysis of produced forms in relation to the general context of its edification. We seek to determine objectively morphological characteristics and to understand its Morphose (action to give form), while providing an adequate explanation for its modeling. An architectural production embodies a system of forms defined by a set of internal relations: that is what we call morphotic structure (Baker, 1986). An architectural form is not isolated; it is considered by its membership in a morphological structure reference. Once the epistemological precautions, it resulted in a defined outline of a general protocol which is mainly based on two different analytical but complementary approaches, which can lead to classifying operations: morphological analysis (Duprat, 2007) and frequency morphometric analysis (Ben Saci, 2000).
2.1. MORPHOLOGICAL ANALYSIS

2.1.1. Structural modeling
Perceptible forms can become intelligible only near elementary decomposition. Characterization of forms is based on the determination of apparent discontinuities or discrete units. The identification of recurrent connections and specific arrangements explain the invisible structures. However, the method poses particular problems of segmentation and definition of morphological structures (Duprat, 2008). This is why it relies in practice on hypothetical carvings, which are validated by comparing multiple specimens to build relevant structural models. Each entity is then treated as an interdependent specimen. Morphological identity emerges from comparison of discontinuities with each others.

2.1.2. Observation, segmentation, analysis and equivalence relations
Segmentation hypothesis is controlled by comparing observations and recurrences. This is the purpose of a structural model: the establishment of equivalence relations between different segments judged counterparts, as well as the explanation of relations across segments and the stability between specimens. The definition of equivalence relations and repeated observations allow perceptual assimilation initial gradually give way to logical operations. Despite its "formalist" referred, this type of analysis has demonstrated its fundamental contribution to morphological studies. Below are presented some study on Tunisian buildings dated from the period 1980 to 2010, either for residential or office purposes (Gharbi, 2011).
2.2. MORPHOMETRIC ANALYSIS

2.2.1. Frequency analysis
It consists in identifying a form by its measurements and by determining its digital data (Figure 3). It can lead to classificatory target. Generally, it is based on transactions and treated codifications followed by mathematical processing of images. Here, all specimens shall be both measured and measuring; a subject that could be a specific research topic. The morphic information is indicated by a vector (energy descriptor) that provides information on the distribution of morphic information about a form in the frequency domain.

Energy description allows the characterization of the form and quantifies the similarities and estrangement between the analyzed forms. Several morphometric treatments are possible, leading to developed applications (Ben Saci, 2000), such as: Morgex, Morphique (Morgine and Promorphe are under development). We use below the two first applications to discuss some results.

2.2.2. Processing by “Morgex” application
We use “Morgex” application to measure codified image by translating it into series of digital values and defining variables in columns of an Excel table. We considered the first 15 data variables corresponding to two topological and configurational levels of studying forms. The similarity or difference between objects is dependent on the values of those variables.

2.2.3. Processing by “Morphique” application
This analysis measures coded images to track changes in its forms depending on frequencies: relative frequency $Fr$, usable frequency $Fu$ and maximum frequency $F_{max}$. It can detect morphic strata, manipulate, and compare them.

3. Analysis and results

We present below examples of morphological process corresponding to morphometric exploration protocols defined above. We proceeded to precise themes of analysis according to a series of assumptions about the fact that the studied forms are organized and composed; the elementary components are not random or arbitrary. We seek to understand the logic of its variation.

3.1. MORPHOMETRIC ANALYSIS OF TRADITIONAL ARCHITECTURE: THE ANDALUSIAN HOUSES OF TUNISIAN AND SPANISH SITES

3.1.1. Presentation of the context

The migration story of "Andalusian people" to Tunisia began before the fall of Granada in 1492. It extended over two centuries before the complete expulsion of all Muslims from the Iberian Peninsula from 1609 to 1914. A total of 46,000 "Andalusian" Muslims from Granada embarked to North Africa. Historians suggest the number of 300,000 "Moriscos" (Muslims living under Christian domination) expelled (Cardaillac, 1990; De Epalza and Petit, 1973). Most of the human transfer went to the Maghreb, especially to Tunisia where were hosted the largest number of "Andalusians", with a favorable policy from the Ottomans, the Turkish authorities who held power at that time. These waves of migrants consisted primarily of wealthy and educated elite, farmers and artisans who chose instead to settle in the interior regions of the country, especially in the north of Tunisia. This installation has been encouraged through attractive donations, in addition to tax exemptions. Thus, in addition to the capital, its suburbs and surrounding areas, "Andalusian" people occupied the towns and villages of Cap Bon, the Medjerda plains and the region of Bizerte; in many cases those "Andalusians" built their own cities (Saadaoui, 2000). Those new elements are integrated into Tunisian society, marked upon their arrival; the cities where they settled and their culture have permeated local society (Bianca, 2000). The "Andalusian" house reflects history as it housed the details of daily life and the people who continue to express their nostalgia for origins.

3.1.2. Corpus and study material

Our corpus consists in certified "Andalusian" houses. The selected sites are located in the North of Tunisia and date from the early 17th century, and they are taken from the South and the East of Al-Andalus, referring to works of contemporary archaeologists of Spanish Muslim sites, now depopulated, principally publications of Bazzana (Bazzana and Hubert, 1993; Bazzana, 1992) and Navarro-Palazon (2005; 1995). Tunisian sites selected are located on the North. We choose two traditional sites per region: the region of Cap Bon (Zaghouan and Soliman) (Badrani 2002), the plains of Medjerda (Testour and Teboursouk) (Saadaoui, 1996), the region of Bizerte (Ras-Jebal and El-Alia) and Tunis (Andalusian Street in the Medina of Tunis and the village of Tebourba). Spanish sites selected are related to four southeast provinces of the Iberian Peninsula, namely Andalusia (Granada, Malaga, Capileira), Murcia (Cieza, Siyasa) (Navarro and Jimenez, 1995), Valencia (Bazzana and...
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Lopez, 1990) and Toledo. In all, we chose a collection of 300 specimens (285 analyzed houses: 165 Tunisians and 120 Spanish for the first analysis and 15 for the feedback step). This, through empirical materials (principally plans); we established a database around the houses and contexts of production (Badrani, 2009).

3.2. THE FORM DESCRIPTOR PARAMETERS FP

When analyzing the form of houses, we identified two types of descriptor parameters: Form descriptor Parameters FP, Use (or functional) Parameters UP, and Architectonic Parameters AP. This article is interested in the firsts, such the characterization of the entire form of the house (plot, roof, floor platforms). We studied the significance of each FP parameter separately for which we considered the study of “variables” corresponding to the frequencies for both topological and configurational levels. A study of intra-variables allowed understanding the relationship with spatial or temporal data. We sought significant morphic data that allowed the identification of degrees of "Andalusity" and / or measure the similarity of the house’s form.

3.2.1. The Built Form Parameter BFP

We found that the above-indicated FP explains differences and similarities between houses. We have proposed classifications according to the Parameter of the Built Form called BFP represented on plan with a morphometric processing. The Properties of the Built Forms are defined using the modeling work as detailed below (Figure 4).

![Plan of the house Zn1](image1)  ![Built Form Parameter BFP of Zn1](image2)

*Figure 4. Codification of Built Form Parameter BFP of the house Zn1 (Zaghouan, Tunisia).*

3.2.2. BFP Parameter analysis by “Morgex” application

Below, is presented an example of treatment for some houses. To facilitate its location, houses are numbered and are called by sites (we retain the first and the last letter of the city’s name, for example: Zn1 and Zn2 mean the houses number 1 and number 2 of Zaghouan city in the northeast of Tunisia. If the name exists we retain first and second letters, such as An1 and An2 which are the houses 1 and 2 from the region of Andalusia, Alhambra-Granada). The analysis is devoted to study similarities between entire forms according to their BFP. House’s BFP was codified by images, before moving to the processing of BFP by “Morgex” (TABLE1).
Then proceed to the identification of significant morphological variables in Zn1 and Zn2. We tried to follow the houses and the first six variables (Figures 5), than we studied the first three variables that correspond to 33 Zn houses (Zaghouan, Tunisia) showing different morphometric variable behaviors (Figure 6).

Those variables can be studied isolated or overlaying. Next were explained variations of BFP as six variables (Figure 7). In addition, we can compare Tunisian and Spanish BFP. We noted more concentration of the Tunisian BFP, and spread distribution for the Spanish houses.

Then, we applied the factorial (multidimensional) method of data processing analysis PCA (Principal Component Analysis) (Casin, 1999; Tournissoux, 2001), particularly by using the WAD application. Variable tables have been formalized under general methods of data processing and multivariate descriptive statistics highlighting classifications, hierarchies and distinctive features that identify this system of forms. Characterization of the factorial axes explained the proximity and measure “morphic distances” between houses according to BFP parameter (Figure 8).
3.2.3. BFP Analysis by “Morphique” application

From coded and processed images by “Morphique” application, we obtained various frequencies: Fr, Fu and Fmax (TABLE 2).

Of all 285 houses studied, we found that the values of Fr vary from 2 to 7 and the Fu ranging from 2 to 9. A combinatory matrix Fr and Fu is represented by the following table, where the index i is calculated resulting quotient Fr / Fu.

<table>
<thead>
<tr>
<th>Images codifies</th>
<th>Niveau topologique</th>
<th>Niveau config. P*Sm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P=1 / A=0</td>
<td>Fmax=1 / Fmax=2 / Fmax=3 / Fmax=9 / Fmax=15</td>
</tr>
<tr>
<td>Zn1 223-420</td>
<td>X: 14.8167</td>
<td>Y: 7.86694</td>
</tr>
<tr>
<td></td>
<td>X: 7.40833</td>
<td>Y: 3.93347</td>
</tr>
<tr>
<td></td>
<td>X: 4.93889</td>
<td>Y: 2.62231</td>
</tr>
<tr>
<td></td>
<td>X: 1.6463</td>
<td>Y: 0.87410</td>
</tr>
<tr>
<td></td>
<td>X: 0.987778</td>
<td>Y: 0.524463</td>
</tr>
<tr>
<td>Zn2 269-318</td>
<td>X: 11.2183</td>
<td>5.60917</td>
</tr>
<tr>
<td></td>
<td>Y: 9.48972</td>
<td>4.74486</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.73944</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.16324</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.24648</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.05441</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.747889</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.632648</td>
</tr>
</tbody>
</table>

We found that 147 specimens (51.57% of the total houses studied) are located in the morphological features area “strongly Andalusian” (A++). It contains the four following intervals [Fr-Fu]: [4-4], [3-5], [3-4] and [3-6]. For example the interval [3-4] includes 37 specimens and has an index i=3/4 = 0.75 (Figure 7). We studied the BFP by site, for example the Zaghouan site (Tunisia), which explained below the map distribution of its 33 houses (Figure 9).
Were noted that 13/165 (7.87%) of Tunisian houses (4.56% of total specimens analyzed) present an “exclusively Tunisian” form character. They correspond to seven frequency ranges. Similarly, 15/120 (12.5%) of Spanish houses (5.26% of total specimens analyzed) are “exclusively Spanish”. The study of the BFP parameter, according to Fr and Fu frequencies, identified the common characters and gives classes of forms; it derives an assessment of the "Andalusity" character degree. That is to say, on this collection, houses can be proved "more" or "less Andalusian" than others. A scale is then put in place to measure them; it depends heavily on the values of Fu and Fr, as explained through the variation diagram of Fu. Then, we identified similarities and differences between the houses as houses Zn9-Zn26 (TABLE 3) and Zn 24-Zn31 (TABLE 4).

"Probably Andalusian" (A)  
"Strongly Andalusian" characters (A++)  
Spanish tendencies (AE++)

"Moderately Andalusian" characters  
Tunisian tendencies (AT++)

"Slightly Andalusian" characters  
Tunisian tendencies (AT+)

"Probably "Exclusively Tunisian" characters  
"Exclusively Tunisian" (E)  
"Exclusively Spanish" (T)

Figure 10. Histogram of "Andalusian" character’s variation according to Fu.

Of all the 285 houses, we retained 11 Tunisian houses (circled in yellow, TABLE 4), 2 of them are from the site of Zaghouan (Zn24 and Zn31), they are framed in red (TABLES 3 and TABLE 4).
TABLE 3. Similar houses Zn9 and Zn26 (Zaghouan, Tunisia) according to BFP.

<table>
<thead>
<tr>
<th>Fr</th>
<th>Fu</th>
<th>Fm</th>
<th>Codified image</th>
<th>Morphic strata [1-Fr]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zn9</td>
<td>3</td>
<td>5</td>
<td>151</td>
<td>![Codified image]</td>
</tr>
<tr>
<td>Zn26</td>
<td>3</td>
<td>5</td>
<td>162</td>
<td>![Codified image]</td>
</tr>
</tbody>
</table>

Thus, we could draw the two hypothetical axes: the Axis 1 (in red, TABLE 4) represents the evolution of forms from "simple" and "compact" to "thin", "multiple" and "scattered." The form contrast, according to this axis is between the houses of Tunisian sites and those of Spanish sites. Is this a coincidence!? The Axis 2 (in green) supports changes in forms from the "multiple", "scattered" and "simple geometry" to the most "thick" and "complex geometry". This second axis represents the time axis. This is a highly probable hypothesis to check later! (TABLE5).

TABLE 4. Examples of houses with singular forms: Zn 24 and Zn31 (Zaghouan, Tunisia).

<table>
<thead>
<tr>
<th>Fr</th>
<th>Fu</th>
<th>Fm</th>
<th>Figure codifiée</th>
<th>[1-Fmax] = [1-3]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zn24</td>
<td>5</td>
<td>3</td>
<td>68</td>
<td>![Codified image]</td>
</tr>
<tr>
<td>Zn31</td>
<td>5</td>
<td>4</td>
<td>89</td>
<td>![Codified image]</td>
</tr>
</tbody>
</table>

TABLE 5. Identification of singular houses forms according to BFP parameter.
4. Discussion and openings: prospects of produced form analysis

This study tried to find links between the architectural form properties of the “Andalusian” houses comparing Tunisian and Spanish sites. It consists in an analysis model with taking into accounts simultaneously various criteria. The most promising are methods which translate qualitative data into digital data. Many instrumental methods were widely explored to measure the produced forms; we exposed some treatments (by “Morgex” and “Morphique” applications) relative to the Built Form Parameter BFP of 285 houses. This work offers the advantage to measure the distance between the specimens by the morphological point of view. It can be valued by the various realized measures, by the morphological variability of the characteristics, and by the variability of houses within the site (same or different sites). It confirms that the local physical and cultural context determine the final quality of the form. Indeed, when the forms are different they could inform about particularities of the data relative to the External Environment (for example, the presence or the absence of patio and its form, the compactness or the manipulated proportions) which were among the specific markers that can inform about the genesis of the site. We tried to define the correspondences between analyzed houses, so as to predict the form of a house from another one chosen as reference. The result is important because it allows a significant distribution of objects according to the geographical space and according to the time axis descriptor. Many external factors have an influence on the architectural form. The value of the BFP parameter is representative from a house to another, it is justified by a spatial and temporal variability; it can be subsequently identified and explained. It confirms the hypothesis that the traditional architectural form of the “Andalusian” house is not arbitrary; to the contrary it obeys specific rules.

The information obtained is interesting but is still incomplete. It requires determining more form descriptors. The experimental method requires more to be operated and perfected, when we wish to obtain more precise information. The form is the consequence of a multitude of qualitative data strongly imbricated the ones in the others. How the measure of the only one of the criteria can reflect its form complexity? It is in the sense that the multidimensional techniques of measure are again promising. In modeling process and knowledge of the form, many other tools will be explored. We propose a new way of seeing the activity of the architectural design and the way of favoring the creation. The proposed work explored the architectural form in link with the creative activity’s borders. What leads to wonder about the doctrines renewal of action for architects?

A critical use of this specialized knowledge would allow defining a better control of the innovation process. We propose to rely on new concepts to develop programming and evolutionary architectural design. Many other tools will be explored to see the contribution of the produced form’s knowledge in the modeling process. We propose to continue analysis of BFP and other parameters; applied to a large number of specimens, the method can be used to measure the forms and explain the similarities and differences; it can allow us to see the evolution of the form and its transformations. Among other things, it embodies the relationships of morphological characteristics and can inform about the degree of “genetic” similarity of objects; it can help to understand the mechanisms of distribution of “Andalusian” houses on Tunisian and Spanish territories.
However, the critical evaluation of this measure method turns out very delicate, and in particular when the criterion which it measures is also complex as forms in its global nature. For that purpose, the operators would have to refer to reliable measurement tools, adaptable in the conditions of analysis and accessible which would have to allow and to direct the outside or internal limits.

Major inconvenience of this approach is that the studies to encircle the form parameters are long and hard and that the development of such a measurement system is long, and laborious, but it is totally operational and can be perfected. A second inconvenience is that this type of method requires the creation of a considerable database and requires being adapted to the collection of objects, for which the model is developed. This database allows choosing the relevant qualitative criteria in large numbers so as to update regularly the model. All the methods if they are descriptive, explanatory or measurable can be useful only when they are combined. Similarly, it would be appropriate to complete the study based on other methods, such as the case of the analysis of the spatial structure of houses by basing on the meadow required by the Theory of graph (Meny, 2005).

Finally, we are looking for how to take advantage of all the investigated methods. The results have sense only when those methods are put in connection with the expectations of architectural designers and intentions. Also it is important to know that the limits of the acceptable base form are in progress. The answer to those questions is variable according to the level of segmentation more than the context’s data.

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SECTION TWO: CREATIVE AND GENERATIVE DESIGN SYSTEMS