MORPHOLOGICAL TAXONOMY AS A METHODOLOGICAL TOOL OF FORM MANIPULATION

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Abstract. The paper presents taxonomy as a methodological tool which serves to better understand the architectural morphose (act of giving shape), and its contribution to form manipulation, produced through a morpho-digital combination. The interest is to exploit digital processes to decipher an underlying architectural grammar. It is thus a matter of releasing the morphological knowledge in conformations (observed forms' system). This orientation stipulates that the produced shape results from a system of morphose which we can formalize and understand by the identification of the structural attributes and the organizational logic, as well as the inherent morphological laws of generation. We stipulate that the interest of our morpho-digital method is the characterization and the development of a constructive morphological model governed by internal relations. Thus, a collection of dwelling buildings is characterized by both the morphology decomposition and the morphometric study. Based on the questions about the form produced, the method promotes a creative situation in the field of architectural design.

1. Introduction

The paper proposes, with the help of the epistemological paradigm (methods and surrounding areas of morphological characterization), a model of management and processing of the morphological information. It is about a proposed new understanding of the produced shape on the basis of the underlying postulates of the architectural shape. The stake is to characterize a morphological taxonomy (1) by the exploitation of processes moved forward in artificial intelligence, allowing observing the laws of regularity, which characterizes a given morphological system. This article defends the necessity of an intermediate positioning which is joining the phenomenal representation of the shape to that digital technology to understand the genesis. The latter is a matter of formalization in both complementary dimensions. On one side, it is a question of revisiting the phenomenological foundations of the morphological similarity; On the other hand, it is about digital characterization's foundations of the architectural shape. The epistemological formalization gives operating results which are leading to a parametric development of the architectural morphology. This work adopts a methodological purpose concerning the laws of identification and manipulation of the forms.

The domain of knowledge of the shape goes through three paradigms mainly: i) phenomenological paradigm bases, the superiority of the physical dimension. A phenomenological experiment does not show the structure interiorized by the shape. It is rather about a description stemming from the perception's experience. It is about representing the shape by its eminent physical properties. M. Heidegger defines the shape as portion of the space limited by an edge which its harmony conveys the reason (1982); it is a figure on a bottom as asserts Gestalt-theory also; ii) empirical paradigm believes on the superiority of the rational experiment allowing to annihilate explanations based on the perception. An empirical discipline maintains its reports with the experiment and the observation (Popper, 1988), as unifiers of objectivity. So, a field of experiment applies digital operating tools on a variant specifically treated for a given architectural corpus; iii) digital paradigm enables to localize the recurring morphological properties, to qualify them, to quantify them to optimize the importance. It is based on new properties of artificial intelligence.

But, a fundamental qualification of the shape is deduced from the integration of the digital tool to check the operations of perception. H.l. Dreyfus asserts the complementarity of two epistemological and 'ontological' indubitable presuppositions (1991) to establish an objective knowledge. Its interest is to overtake the epistemological obstacles put by both previous paradigms (2). He displays an approach which combines the phenomenological definition of the shape in the purely experimental definition. We develop a dynamic conception of the shape which federates within a qualifying and forward-looking combined reflection. The morpho-digital modelling articulates qualificatives and quantificatives purposes. We agree that the morphological formalization reveals two degrees of understanding: i) the analytical morphology displays a qualifying moment, using digital investigation on the shape phenomenologically studied; ii) the morphometric method constitutes a quantifying moment which pleads the conversion of every shape studied in numerical values regulated by means of internal frequencies. Those support the comprehension of the produced shape and the projection of the shape to be produced.

2. Morpho-digital Method For The Architectural Forms' Analysis

2.1. CORPUS AND STUDY MATERIAL

Our methodological investigation concerns a collection of 95 facades of residential buildings constructed between 1990 and 2015. It is about a new district on the periphery of the capital Tunis, *Ennasr*, whose buildings respect specific rules and regulations of town planning in the zone. The facades, included in our study, present on the morphological plan a source so rich with morphological combinations. We do confirm the release of the morphological values interiorized in the conformation of the facade. What allows to report combinations' rules which govern an underlying morphological system. B. Duprat defines the façade's addresses as a rich support which supplies multiple analycities (capacities to be analyzed), being a matter of an autonomous morphological structure (1999). Facades reveal an underlying morphological knowledge to be clarified. We work on the basis of statements of facades reproduced in linear mode then codified in levels of grey, and handled by specific software to the study of the architectural shape.

TABLE 1. Exemples of current facades

2.2. FORMALIZATION OF MORPHO-DIGITAL COMBINATORY

2.1.1. Patterns of Morphological Composition

The morphological analysis and the morphometric modelling constitute two analytical models of the produced shape. The morphological analysis is a first operation of morphological objectification. The decomposition sets up a system of interstitial morphological relations between parts and parts and the whole. It is necessary to observe the morphological obvious discontinuities of the objects; decompose (through reflection) each of the specimens of the collection into different segments. The morphological segments of the whole are definable because they are bounded (and their perceptible limits are the discontinuities forming borders between adjoining segments). It is what, b. Duprat considers as a source of legitimacy of the method (1999). Those considerations reduce the relations possible for a very small number, and eliminate the weak relations between objects and their segments. A morphological structure is stopped further to operations of comparisons inter and intra-specimens. So, to decompose the facade, it is necessary to go through 1) the location of the recurring obvious discontinuities by the various conformations; and with regard to a hypothesis of homology; 2) the Transport / Coupling of the discontinuities, which we appoint by segments, to reveal or deny homologies; 3) the definition of structural model (s). The comparison between the whole and its parts and between the parts themselves trains an operation of control and validation of the most convincing morphological hypotheses.

The morphometric modelling proposes the second pragmatic objectification. It imputes within a model of morphic information (quantified morphological information); where it becomes possible to measure the shape, calculate its morphic potential and estimate its contribution regarding morphic information. The morphic experience displays tools of mathematical calculation. The digital measures are governed by an energy description in a field of variable frequencies distributed on 15 frequencies' domains. Every frequency domain constitutes a frequency band BF which corresponds to an elementary morphic composition. The shape is defined according to: a topological space (corresponds to morphic information retained on first morphic strata corresponding to the primary frequencies), and a configurationnel space (informs about levels of frequential stabilizations of morphic strata). The frequential analysis displays specific digital tools. On the software 'Matlab', the 'Morphique' application reveals the behavior of the shape according to the variation of the frequencies. The 'Morgex 'application is used to measure codified images and translates them into a series of digital values defining variables in columns of an Excel table. The tool ' Wad ' allows the statistical processing of the digital data.

2.1.2. Structural Matrix

In the process of characterization, the parameters of position and depth set up two matrixes of comparison and structural control. The matrix of position allows clearing the laws of morphological stability according to the horizontal pile of the parts. However, the deep matrix clarifies the origins of the volumetric stratification. According to its position, obviously, each party corresponds to a segment. It is possible to project the latter according to its position from a specimen to the other one. This is what we call a projectable property.

2.3. MORPHOLOGICAL OPERATORS

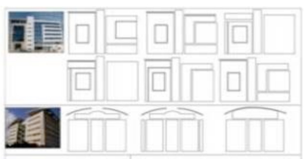
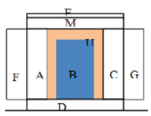
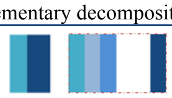
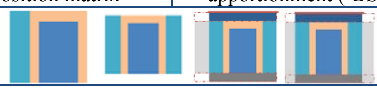
A visual operator is deducted from the of the position's matrix on specimens. The comparison's operations and structural control are based on the parameter of linear positioning. A digital operator results from the application of the depth matrix. It is translated in values of variable frequencies which we indicate by energy descriptors.

3. Results and Discussion

3.1. MORPHOLOGICAL ANALYSIS AND DATA PROCESSING

We proceed to the analytical decomposition of the facades’ specimens. We choose the position as mode of apprehension of the structure, locating the discontinuities or the segments, defining the homologies of position as descriptor of constitution (equivalent segments from a specimen to another one). Then, we establish a comparison based on those visible structural homologies. This allows the validation of structural models by the formalization of its intrinsic morphological relations. This method calls on the digital tool 'BSK' to facilitate the classification and the data processing of decomposition, comparison and morphological control. The segments of strong importance constitute the morphological attributes of comparison inter-specimens; which leads to their categorization in families of the morphological structures, according to the eminent attributes. The elaborated work asserts that the conformation of facade is a morphological system which hides two typologies of internal structures. A first category shows a structuring by linear juxtaposition of spans. The second reveals a structuring in main span of order with possibility of presence of symmetric or unilateral side bodies. We do summarize in the following picture the stages of morphological decomposition.

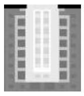
TABLE 2. Structural modelling steps

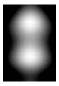
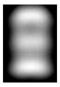
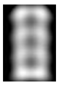
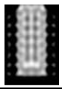
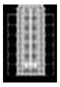
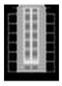
 Elementary decomposition	 Position matrix	 Specimens/Attributes apportionment (‘BSK’)
		
Structuring by linear stacking spans	Structuring by main sequence span	

3.2. FREQUENCY ANALYSIS AND DATA PROCESSING

For every specimen corresponds a frequency storyboard. It allows to survey the structural evolution of the form from the embryonic structures on the frequency bands. What clarifies a morphological cycle, and reveals a structuring in elementary morphic skeletons.

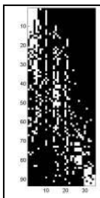
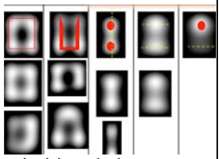
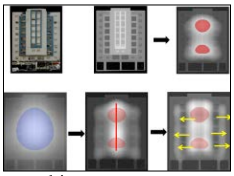
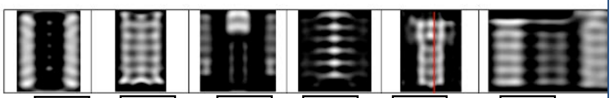
TABLE 3. Example of morphic storyboard.

Codified facade 

BF1-2	BF1-3	BF1-5	BF1-7	BF1-10	BF1-15	BF1-23
						

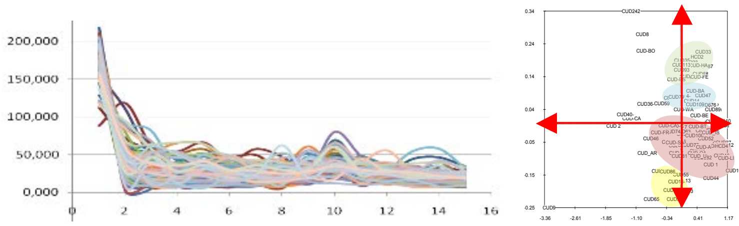
The shape's cycle contains three essential phases: the disturbance (BF1-3, 1-5, 1-10), the temporary stabilization (BF1-2, 1-7) and the refinement (BF1-15, 1-23). It sends back to the parameter of morphic tectonics. 'BSK' reveals categories of elementary morphic skeletons held by the BF.

TABLE 4. Morphic tectonic parameter (follows morphic behavior).

 Evolution	 primitive skeletons	 morphic emergence	Morphic behavior : 1-Monobloc with alveoli 2-Configuration in 'I' + cellular divisions + lateral disturbances 3- Repetitive verticality 4- Horizontal stack 5- Configuration in 'T' + cellular divisions 6- Configuration in 'U'+ cellular divisions + horizontal disturbances
 1 2 3 4 5 6			

With the application 'Morgex', we get frequency curves from each codified facade specimen. The superposition states that specimens in the collection have large structural homologies. The clouds of points table is obtained after integration and processing of values calculated by 'Morgex' on 'Wad'. It shows specimens concentration areas. It is qualified in relation to axes U1 and U2.

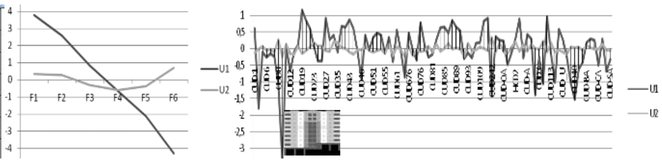
TABLE 5. Superposition of frequencies' curves and point cloud table.



To optimize the interpretation of the data, we proceed to their superimposing (Figure 4); this reveals a main frequency domain where are located the majority of specimens. The general morphic information is situated in the field of frequencies [-1, 0.6]. The more obtained frequency value aims towards 1, the less is the structure's depth. It is governed by a main span of order with regard to a back body. The more the frequency value aims towards [-0.6], the more the structure presents a high quantity of morphic information. So, the morphic potential establishes the second morphic parameter determining the depth. The morphic structure corresponds, in this case, to a complex combination of juxtaposed and superimposed spans of bays, balconies. The morphic depth becomes so remarkable.

TABLE 6. Superimposing of frequencies' axes and localization of specimens' distribution

	U1	U2
F1	3,767	0,335
F2	2,566	0,28
F3	0,808	-0,316
F4	-0,682	-0,598
F5	-2,144	-0,389
F6	4,315	0,687

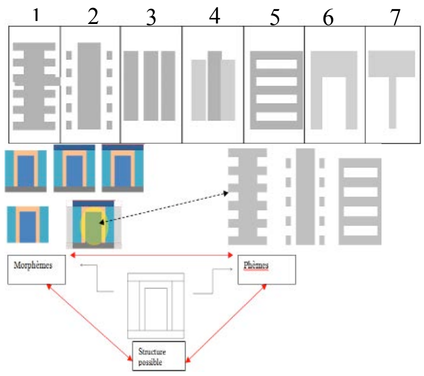


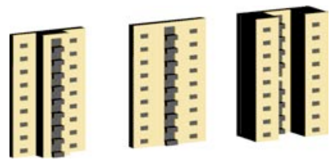
3.3. MORPHIC FACTOR

The morphic factor results in the morpho-digital combinatory. It is projectable by three properties: the morphic tectonic or the morphic depth, the potential of morphic information, and the inter-relation between the parts and the whole. The interstitial laws are summarized at the origin of the structural convergences between attributes: the span of order or simple, the main body, the back body or the side body. The latter are summarized by a taxonomic matrix. The morphic tectonic is underlying to a structural evolution's cycle, made in similar elementary primitive embryonic skeletons. The potential of the morphic information depends on the corresponding structural system. More it is complex; the structure demonstrates an important morphic depth.

Thanks to the evolution of the artificial intelligence tools, it becomes possible to plan the same structures in an infinite way. What supports the manipulation of the shape by its elementary attributes with its own morphic operators. All the morphic relations identify the general morphological matrix. The back body (Ar C) shifts from a main position, in this case we hold the relation Ar C/To, or secondary one obeying the relation To / Ar C. This structural typology governs all the other elementary components, this is applicable for side body (CL), front body or main body (AC). The span of bays (Tb) constitutes the most important attribute of the corresponding specimens. Each can establish in certain cases a span of order. Its central position makes set up a symmetric or asymmetric organization according to the choices of the designer. The span of order (To) respects two morphic topologies: i) simple by superimposing either of bays or set back masses or masses in projections; ii) combined where it shows morphological structure based on the combination of simple span by linear or volumetric juxtaposition; iii) (To) can be associated with the main body (Cp) in projection or set back position. We conclude the following structural relations: T_o=Ar C/T/ (C_p or AC);

TABLE 7. Matrix for morphological manipulation





1- Span in ‘I’
2- Span with lateral detached bodies
3- Repetitive separated spans
4- Span with lateral adjoined bodies
5- Monobloc span with alveoli
6- Simple or composite span in ‘U’
7- Simple or composite span in ‘T’

4. Conclusion

The morpho-digital combination supports the formalization of a theory applied to the domain of the architectural shape. This theory associates two modes to identify the shape. It questions in particular the utility to assign a theoretical knowledge of the shape to a digital field of application. On the epistemological plan, the morphometry reveals methodological tool of ontology of the produced shape; this builds itself from the conversion in objective values of an ‘objectivable’ (capacity to be objective) shape. It is an innovative track which comes to complete a rich structural morphological analysis by its contents and limited by its ways. It adds to the shape's understanding by visual assertions objective mathematical solutions.

The current facade, support of our present study, hides a structure which is able to be formalized through a morphic factor. The latter expresses morphic parameters. A morphological objectivable logic which rests on a knowledge and a know-how and which sets up the laws of generative manipulation is demonstrated. The formalization of an underlying morphological taxonomy reveals the typologies and the laws of the morphological organizations of specimens in question. Thanks to the morphometric tools, the form federates in an objective quantitative definition. The characterization based on the morphological taxonomy contributes to the development of a constructive morphological model. The latter sends back to operations of regulation in a spiral which aims towards the infinity (Le Moigne, 1999). Consequently, the shape possesses double epistemological purposes: epistemic purpose which stimulate the acts of morphological objectification, and the methodological purposes which develop the experimental methods. This work opens new perspectives of computer-aided design. So, it establishes a creative method resulting from a combinatorial morphological strategy. The generation of the shape becomes possible just as we manage to define all the morphological behavior which governs an existing architectural object or to produce. After decrypting its epistemological contribution in a genetic knowledge of the shape, it becomes possible to manipulate it.

References and Notes

1-The taxonomy is defined as the study of the diversity of the human beings and the clarification of its causes of this diversity. The field of the discipline extends the description in the analysis of the relations between types until the expression of the results under a codified shape (Cnrtl.tn, 2016).

2-By ontological, Dreyfus reminds the phenomenological dimension which he criticized at Heidegger; he considers that the latter presents a definition of the existence which is lacking internal articulations contrary to Husserl (1991,p.30)

BEN SACI A., 2000. *General theory of the architecture, morphometry and systematic modeling*. Ph.D. diss., Jean Moulin-Lyon 3 University.

DREYFUS, H.L., 1991. *Being in the world, a commentary on Heidegger's being and time*, division1, ed. MIT Press London, 30-40.

DUPRAT, B., 1999. *Morphology analysis applied to architectural conformations, its problems, its principles, methods*, ENSAL, Lyon.

DUPRAT, B., 2009. Master course. *Structuring of Lyon facades of the 19th century,* Enau High school.

GHARBI A., 2011. *The new façade in Tunis: morphological exploratory study of buildings 2000-2010*, Master's Thesis, ENAU, Tunis.

HEIDEGGER. M., 1962, *Le principe de la raison*, ed. Gallimard France, 135.

LE MOIGNE, J.L., 1999. *Les épistémologies constructivistes*, ed. Puf Paris, 99-117.

POPPER, K., 1988. *Misère de l'historicisme,* ed. Pocket Angleterre, 45.