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Alia Belkaid, Abdelkader Ben Saci. Urban Morphological Rules Classification for Digital Design. Journal of Civil Engineering and Architecture, 2021, 15 (4), pp.175-180. 10.17265/1934-7359/2021.04.001 . hal-03247987

HAL Id: hal-03247987
https://hal.science/hal-03247987

Submitted on 3 Jun 2021

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Journal of Civil Engineering and Architecture 15 (2021) 175-180
doi: 10.17265/1934-7359/2021.04.001

DAVID PUBLISHING

Urban Morphological Rules Classification for Digital Design

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Abstract: The hidden dimension of the urban morphology is the underlying the urban morphological rules system. The number of these rules has increased and their application tends to become more complex. The urban morphosis based digital approaches tends to become widespread. However, achieving the target values for all the rules is difficult. This impacts the social, environmental and aesthetic objectives of these rules. This paper proposes a classification of urban morphological rules to assist the digital morphosis of urban form. The aim is to endow the system of rules with a hierarchy, which can make efficient the automatic generation of the urban forms respectful of the urban law. Thus, this work promotes the concerns of artificial intelligence in urban morphology.

Key words: Artificial intelligence, rules classification, digital moprhosis, urban morphology, urban rules.

1. Introduction

The shape of the buildings of a city is dependent on urban morphological rules [1]. These function as a controller interface for urban morphology. Several architectural achievements have proved this (Schaulager near Basel, Prada in Tokyo) [2]. The shape of these buildings depends on urban rules from the first moments of design to a regulatory optimization (Fig. 1).

The density indices have allowed a variety of urban forms since their introduction in the 1950s. They have helped to avoid the monotony of cities layout [3] and have given better quality of buildings [4]. These indices have allowed freedom of architectural production and brought many changes in the urban morphology [5].

In the era of artificial intelligence [6] and digital approaches to urban morphosis [4-7, 8], this paper proposes a classification of urban morphological rules to build intelligent devices to generate urban morphology. The idea is to observe whether there is an intrinsic hierarchy of rules, a principle of primacy enables to give an order and to facilitate the urban morphosis assisted by artificial intelligence.

2. Urban Morphological Rules

A corpus of 12 urban morphological rules is made up through the examination of the Tunisian urban planning, Paris urban regulation and Moro studies [9]. It is defined as follows: (1) the **alignment** is the dividing line of a highway and waterfront properties; (2) the **Building Coverage Ratio (BCR)** is the ratio of the building area divided by the plot area; (3) the **Floor Area Ratio (FAR)** is the ratio between the total covered area of all the floors and the total plot area; (4) the **constructability context** defines the limits of the building layout area on the building lot; (5) the **patio size** determines how large a *patio* should be; (6) the **distance between the buildings** of the same plot; (7) the **maximal height** limits the elevation beyond which it is not possible to construct; (8) the **roof slope** defines an inclined plane which limits the roofs of constructions; (9) the **setback from roads** is the ratio between the width of the street and the height of the

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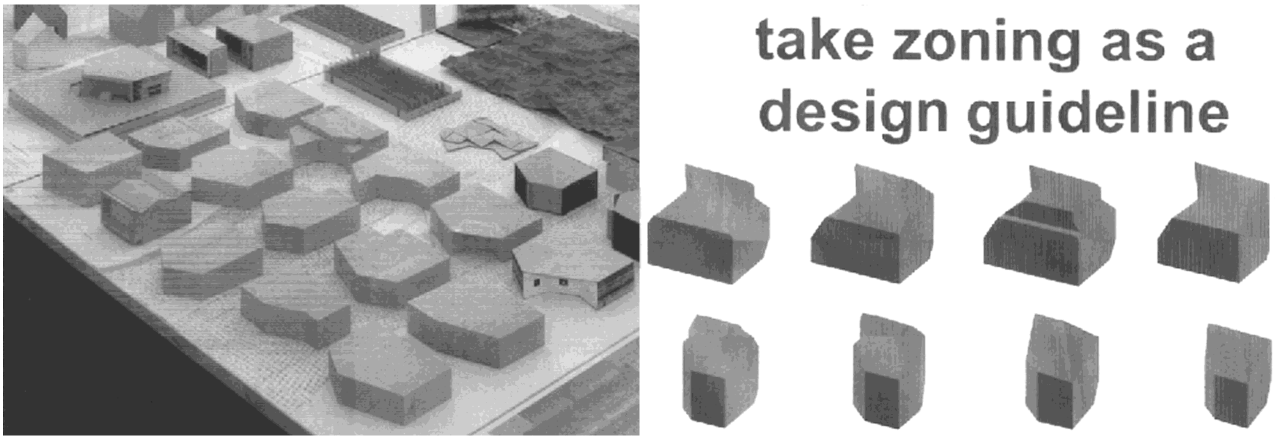

Fig. 1 Study models of Schaulager (left) and Prada (right) [2].

urban façade; (10) the **setback from common limits** defines the location from the boundaries separating the parcels. It determines the minimum distance of a building relatively to the adjoining boundary depending on its height; (11) the **servitude of light** ensures access to natural light for buildings situated in a dense urban fabric; and (12) the **servitude of view** is the right to enjoy a view.

3. Classification of the Urban Morphological Rules

The urban rules influence three areas of the urban form: the public space, neighborhood and the private space [10]. The road rules manage the public domain. They concern the alignment, the setback from roads, the maximum height and the roof slope. The hygienic rules manage the inter-plot neighborhood area. They define the relationships between the buildings belonging to neighboring plots. They take into account sunshine, natural lighting and ventilation. The density rules manage the private domain (intra-plot rules). They define the conditions related to one or more buildings belonging to the same plot. They concern the constructability context, the BCR, the FAR, the distance between buildings belonging to the same plot and the size of patios.

The urban morphological rules do not have the same frequency in urban regulations of cities. Certain rules are frequently used and can be described as widespread. Other rules are infrequent and can be qualified as rare.

We construct a disjunctive matrix describing in rows the 12 morphological urban rules and in columns the status of the urban rules (public, neighborhood, private) and their frequencies of use (widespread, rare). The dichtomic coding (0, 1) is transformed into an information measure according to Shanon's theorem. Then we apply the serration technique which alternately orders the rows and columns of the matrix from the only intrinsic information describing the urban morphological rules. The scalogram obtained reveals data patterning and underlying hierarchical order (Fig. 2).

Crossing the properties of the status with the frequency (Table 1) makes possible to associate the couples (status i, frequency j) to the rules. These couples reveal an underlying order of urban morphological rules. The status i defines the priority for using the rule. The frequency j qualifies the preponderance of its application.

To make the classification discriminatory, we propose to introduce the criterion of seniority of the rule which indicates its importance. The table codes in addition to the status and frequency, the old rules (from antiquity to the 19th century) by 1 and the recent rules by 0. We perform a transformation into an information measure then a serialization analysis of the data. The resulting scalogram (Fig. 3) allows classifying the urban rules according to their age and the frequency of their use. We note the existence of a close link between seniority and the preponderance of the morphological rules in planning regulations. The oldest rules are the most widespread. The most recent rules are quite rare. The seniority qualifies the rank (importance) of the rule.

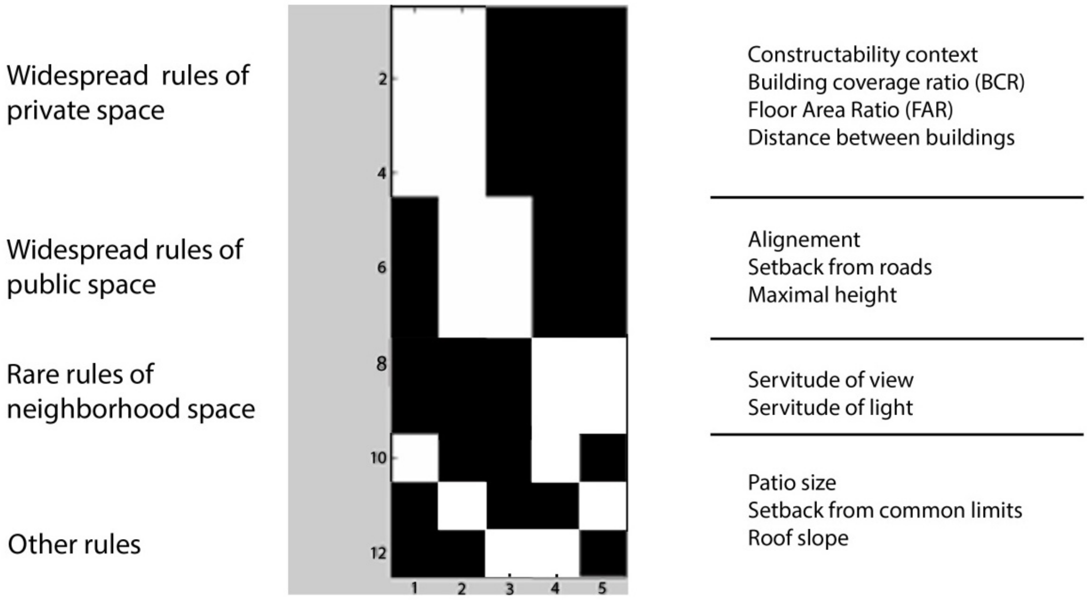

Fig. 2 Guttman scalogram of the 12 urban morphological rules described by status and frequency.

Table 1 Classification of urban morphological rules by pairs (status i, frequency j).

Frequency (j) \ Status (i)		1 Public	2 Neighborhood	3 Private
1	Widespread	(1, 1)	(2, 1)	(3, 1)
2	Rare	(1, 2)	(2, 2)	(3, 2)

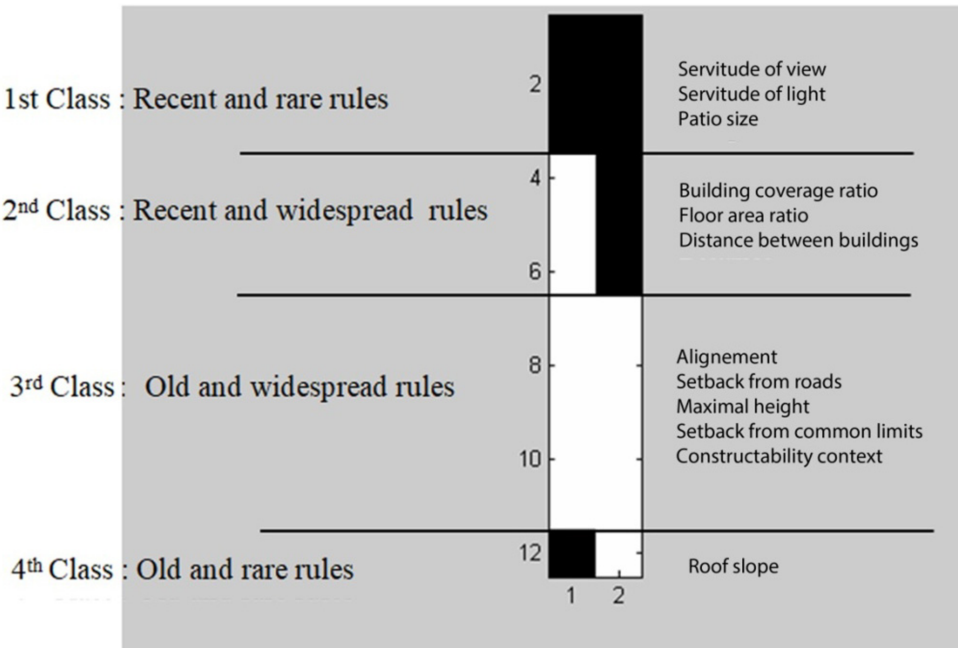

Fig. 3 Guttman scalogram of urban rules described by frequency and seniority.

4. Results

This fine analysis of the urban morphological rules enables to formulate proposals of principles for the generation of the urban morphology assisted by artificial intelligence. The three criteria Status, Frequency and Rank allow defining a hierarchical principle of urban morphological rules application in an automated morphosis system.

It is possible to distinguish one rule from another according to its status, frequency and rank. The status of the rule (public, neighborhood, private) gives a first order.

It defines the emergency treatment of the rule. The status is coded by an integer between 1 and 3. Status 1 corresponds to the oldest area of influence: the public domain. Status 3 corresponds to the most recent area of influence: the private domain. Status 2 corresponds to the intermediate area of influence: the neighborhood area.

The second order is defined by the frequency (widespread, rare). This qualifies the preponderance of the morphological rule in the definition of the urban shape. A preponderance coded 1 corresponds to a widespread use and coded 0 corresponds to a rare use of the rule.

The third order is defined by the rank of the rule in the definition of the urban form. It characterizes the importance of the rule in a given class. Each class contains more or less important rules. The qualification of the importance of a rule is linked to its seniority, but also to designer arbitration when two rules appeared at the same time, such as density indices. The rank gives rise to an ordinal code between 1 and 5. The first row corresponds to the oldest rules. The last row corresponds to the most recent rules.

Each urban morphological rule has a priority, preponderance and an importance designated by the triplet (i, j, k). The variable "i" corresponds to the status. The variable "j" corresponds to the frequency. The variable "k" corresponds to the rank. The hierarchy of triples (i, j, k) gives an order (n) of application allowing the rules to be classified in ascending order. The rule with the lowest value (i, j, k) will have an order 1. The rule with the largest value will have the largest order. The reverse of the order of application (1/n) of the urban rules gives a weighting coefficient for the weight of the rule. This allows weighting the calculations in an automated system for generating urban forms (Table 2).

Table 2 Classification of urban morphological rules.

Urban rules	(Status, Frequency, Rank) (i, j, k)	Order: n	Weight of the rule: 1/n
Alignment	(1, 1, 1)	1	1
Setback from roads	(1, 1, 2)	2	1/2
Maximal height	(1, 1, 3)	3	1/3
Roof slope	(1, 2, 4)	4	1/4
Setback from common limits	(2, 1, 1)	5	1/5
Servitude of view	(2, 2, 2)	6	1/6
Servitude of light	(2, 2, 3)	7	1/7
Constructability context	(3, 1, 1)	8	1/8
BCR	(3, 2, 2)	9	1/9
FAR	(3, 2, 3)	10	1/10
Distance between buildings	(3, 2, 4)	11	1/11
Patio size	(3, 2, 5)	12	1/12

5. Discussion

This approach orders urban morphological rules to help generate regulatory urban forms. These rules are authorizing bounding box responding to a given regulatory context.

The weighting coefficients give regulatory urban forms a relevance which prioritizes the value of urban morphological rules. These hierarchical rules build a morpho-regulatory "reference space" which gives measure [11] to the authorizing bounding box. This reference space has regulatory and historical relevance. It gives an intrinsic order to the morphological rules according to priority, preponderance and importance.

The application of the urban morphological rules without hierarchical classification often results in conformed but not optimal forms from a regulatory point of view. A regulatory form governed by urban morphological rules complies with the regulations, but it is not necessarily optimal. It is therefore useful to distinguish compliant forms from the optimal regulatory forms. The first ones respect the urban regulations but are not necessarily maximal. The second ones offer maximum benefit from the regulatory context by managing as well as possible the conflicts between the urban morphological rules to reach the best urban targeted rules. Thus, this approach has a direct impact on urban density, which is a major issue in the urban morphology of current cities.

This paper proposes a model of organization of the morpho-regulatory reference space to give measure to optimal regulatory forms. Depending on the design situation, it generates a single or multiple authorizing bounding boxes. If the authorizing bounding box is single, the morpho-regulatory reference space is sufficient. If the authorizing bounding box is multiple, the automatic processing turns out to be insufficient and requires an external convergence condition such as arbitration by the designer or the integration of non-regulatory constraints.

6. Conclusion

This paper aims to contribute to the era of artificial intelligence to automatically generate optimal urban forms through urban morphological rules. It endows the urban morphology with morpho-regulatory relevance. It deduces, from the classification of morphological urban rules, a hierarchical principle of their application in an automated morphosis system. It builds an operating morpho-regulatory reference space for the generation of optimal authorizing bounding box. It orders the urban morphological rules in a hierarchical model in order to assist the digital morphosis of urban forms from a regulatory point of view. The hierarchy classifies the rules in an increasing intrinsic order and proposes an order of application. This takes into account the status, frequency and seniority of the rule. It proposes weighting coefficients to integrate, into the digital morphosis, the notion of priority (status), preponderance (frequency) and importance (rank) of the urban rule. This will enable to classify the bounding box generated according to the result of the rule weights.

The model has the advantage of being open and extensible. Being open because it accepts to be initialized in different ways and being extensible because it accepts new rules.

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