A Grammar for the Patio Houses of the Medina of Marrakech

Towards a Tool for Housing Design in Islamic Contexts

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The goal of the research described in this paper is to develop a computational model of the Medina of Marrakech in Morocco. The ultimate goal is to develop a system that could capture some of the characteristics of traditional Muslim cities fabric and use it in contemporary urban planning. Previous papers have proposed the use of three grammars to encode the spatial complexity of the Medina: the urban grammar, the negotiation grammar, and the housing grammar, and addressed the development of the urban grammar. This paper proposes a grammar to describe the formal structure of the houses, the first step in the developments of the remaining two grammars. It describes the set of rules and then illustrates its application in the generation of an existing house. The basic formal structure consists of three concentric rectangular rings with the patio in the middle. The location of the entrance and the staircase are fundamental for the definition of the basic layout.

Keywords: *Shape grammars; housing design; Islamic architecture*

Introduction

The research described in this paper is part of a larger on-going project that aims at incorporating shape grammars (Stiny and Gips 1972) with an existing generative design system (Caldas 2001) based on genetic algorithms. The ultimate goal is to develop a computational system for generating novel urban and housing configurations that are more sustainable and energy efficient, while respecting certain cultural, urban, and architectural characteristics, as captured by the shape grammar. This research draws on the previous implementation of a generative for generating architectural objects using genetic algorithms and on the application of shape grammars to customized mass-housing, (Duarte 2001) but the work presented here takes the Marrakech Medina as its architectural precedent.

The reason for choosing the Marrakech Medina as the case study for this experiment was threefold. First, this particular urban fabric was attractive because of the intricate connections between the urban configurations and the patio houses. Only the systematic use of the patio-house typology could allow for the emergence of an urban tissue with such complex characteristics. From this point of view, the investigation of the possible application of this housing type, so fundamental to the Islamic culture, to contemporary housing developments is a very interesting research question. Second, previous work (Rocha, 1995) that constituted an early effort to characterize the urban and architectural patterns of this

area, suggested that a stylistically coherent corpus of designs existed and that it had enough variety and richness to fit the research objectives. Third, the population increase that occurred in Marrakech during the last decades, as in most North-African and Middle-Eastern cities, has led to an uncontrolled urban growth that produced urban environments lacking the spatial richness found in historical vernacular districts. Thus, this research intends to provide a computational framework that can assist designers in the design of urban environments that maintain traditional spatial and compositional principles while satisfying the requirements of modern life.

A quick look at an aerial view of the Medina of Marrakech suggested an organic and almost chaotic city growth. However, a close analysis unveiled a well-established order with repeated urban patterns. Such patterns are not geometrically but topologically similar. Consequently, it was possible to encode the identified patterns into a reduced number of parametric schematas, turning the grammar into a parametric shape grammar.

At the outset of this research, it was considered necessary to deal with both the urban scale and the scale of the house by developing two independent grammars: an urban grammar that would account for the urban layout, and a housing grammar that would account for the functional organization of the houses. As the study evolved, it was realized that these two grammars could not be fully independent. In fact, the functional organization of the houses seemed to be partly responsible for the geometry of their perimeter, which varied on different floors in the same house, causing the house to interlock with neighbouring houses. As such, pre-established rectangular lots alone could not account for the generation of existing houses. This obliged to consider an interaction between the design of the houses and the urban layout and a third grammar was proposed as a result. This grammar, called "negotiation grammar," mediates between the other two grammars and regulates the permutation of spaces between adjacent lots according to the necessities of their owners. It is not certain that this "negotiation" between neighbours actually shaped the patio-houses as not enough historical evidence was found. However, considering the close families ties that characterize Islamic society, to consider that it did exist is not far-fetched. In fact, only a society with this tight-knit social environment could have produced such complex spatial configurations. The use of three grammars permitted to reduce the complexity of the problem.

Previous work has addressed the development of an urban grammar that accounts for the generation of the urban fabric. Current work is focused on the development of a shape grammar for the design of the patio-houses and it articulation with the urban grammar through a set of rules encoded into the negotiation grammar. This paper focuses on the development of a grammar to describe the formal structure of the houses. First, it presents the corpus of houses used to define the grammar. Second, it describes their formal structure. Third, it presents the set of rules that form the grammar. Fourth, it shows its application to the generation of one of the existing houses. The paper concludes with a discussion on the use of the housing grammar in articulation with the urban grammar.

Corpus

Because it was difficult to have access to houses in the *Zaouiat Lakhdar*, the quarter used to infer the urban grammar (Duarte et al, 2006), only three of the houses in the corpus were located there. (Figure 1) The remaining houses were located in neighboring quarters. However, this had no impact on the study because a preliminary survey suggested that the houses had the same formal structure. The grammar was developed after a corpus of eight Medina houses *(Dar): Dar 27, Dar 33, Dar 73, Dar Dounia, Dar Frances, Dar Charifa, Dar Hannah*, and *Dar Fondouk*. (Figure 2) Social and cultural characteristics of urban planning and architecture, as well as many aspects of Islamic social behavior are related to the Islamic law, *Shari´ah*. This set of religious public values and rules determine

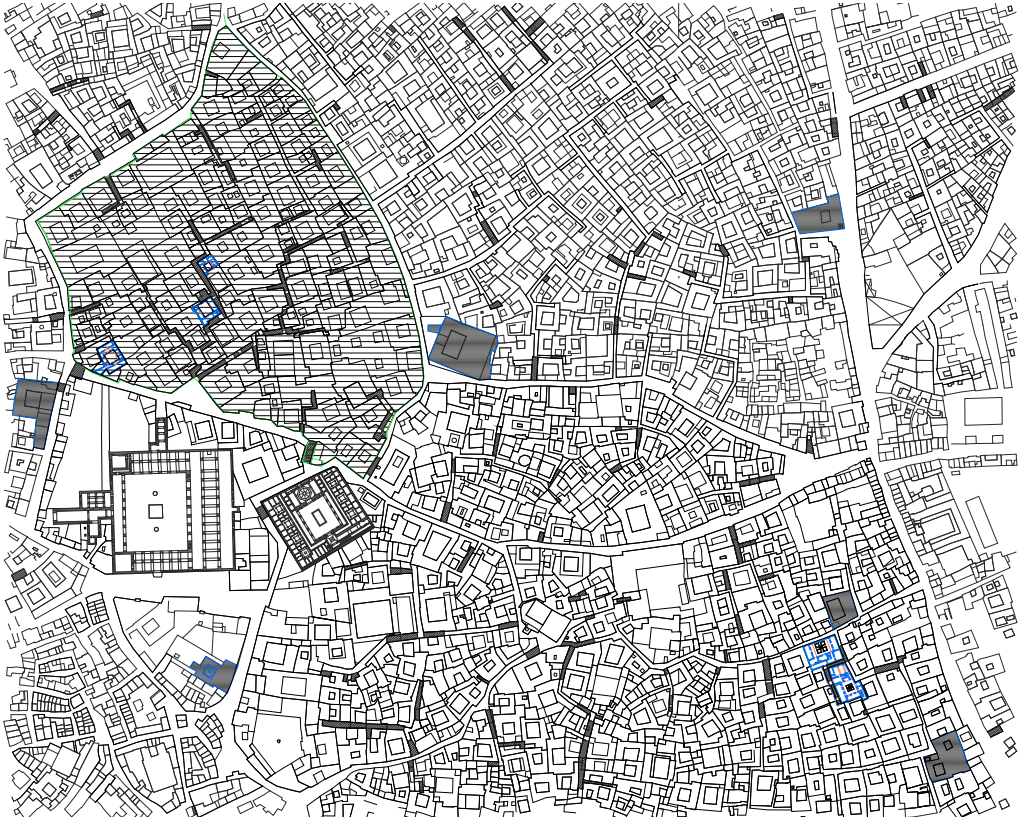


Figure 1
Map of the Marrakech Medina showing the location of houses in the corpus.

many of the social patterns of Islamic society and its urban and architectural spatial configurations. As mentioned in the *Qur´an*, the family is the most fundamental element of Muslim society where strong family ties are expected to last. As a result, it encourages extended forms of family living in a single house. This partially explains the organization of domestic architectural spaces which are close to each other and contain multifunctional spaces surrounding a courtyard. Usually a courtyard house is a two-storey building constituted by narrow and long rooms (*bayt*) placed along the perimeter of the house and enclosing the patio on its four sides. Frequently, the layout of each *bayt* arranges itself in a geometrical form that takes the irregularities of the surrounded urban fabric, but at the same time it keeps its walls with a 90º angle along the courtyard so that the regular geometry of the patio is preserved. The *bayt* plays a key role in the

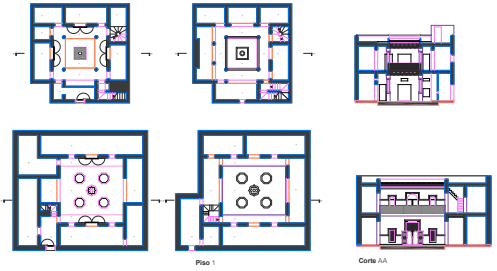


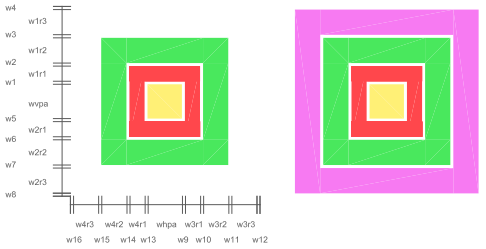
Figure 2
Two houses in the corpus. Top: Dar Foundouk, bottom: Dar Frances. Legend: 1. main entrance (bab al-dar), 2. stairs (drug al-'ali), 3. entrance hall (sqifa), 4. interior courtyard (hosh), 5. gallery (burtal), 6. room (oda), 7 iwan (iwan), 9. corridor (mgaz), 11. veranda (darbuz), k. kitchen (matbakh), L. latrina (mirhad).

Figure 3
The basic pattern of the formal structure underlying the Marrakech Medina houses: two or three rings around the patio.

domestic organization of the building cell as it has to have a highest functional flexibility either as the master bedroom or as a room that has to be transformed into an independent family unit as a consequence of an extended family. Access to each room is from the courtyard and usually there are no interconnecting doors between these spaces. They are lighted exclusively by windows that open onto the patio and the most important room is located furthest from the house entrance. The stairs, which always occupy the minimum space possible, are usually located at the corner of the house or close. The geometry of the patio is associated to its rectangular or square form and has one principal axis of symmetry punctuated by the entrances to the bayt, which face each other at the centre of the patio walls. It is worth mentioning that unlike domestic roman courtyard house *Domus*, the symmetry of this type of house does not involve the whole building. Frequently the houses extend asymmetrically to neighbouring houses or over the street, forming spaces called *sabbats*. The patio is primarily for private use and although most houses host modest courtyards others from wealthy families have patios with considerably large dimensions. For more information on the functional organization of the Medina houses see Wilbaux (2001).

Basic formal structure

The analysis of the houses revealed an underlying pattern formed by two rectangular rings around the patio (Figure 3). The first ring corresponds to the loggia and the second ring to the rooms. These rings might be complete or incomplete, meaning



that they can have one, two, three or four sides. In some cases, it is possible to consider the existence of a third ring that accommodates additional rooms or might be used to extend the rooms in the second ring. This ring is usually incomplete.

The dimensional analysis of the houses in the corpus permitted to establish the range of variation of the dimensions and proportions of the basic pattern, which are summarized in Table 1. For instance, the width of the patio (wwpa) can vary between 3.0 m and 8.04 m, and the length (wlpa) between 3.59 m and 8.10 m. The shape of the patio can vary between a square and a rectangle with the proportion 1:1.3 (approximately 3:4). However, the survey of all the patios in the Zaouiat Lakhdar quarter using the aerial photo showed that the proportion could reach 1:4 (approximately 1:√2). The depth of the first ring (wr1) can vary between 0.70 and 1.41 and it is between 0.17 and 0.31 of the patio's width (wr1/wwpa) and between 0.14 and 0.31 of the patio's length (wr1/wlpa). Also, the variation of such depth within the same house is such that the depth of the narrowest side of the ring is at least 0.83 of the depth of the widest one (wr1 min / wr1max). The dimensions and proportions of

Table 1
Dimensions and proportions of the Marrakech Medina houses

	wwpa	*wlpa*	*w1,5,9,13*	*wr1*	*w2,6,10,14*	*wr2*	*w3,7,11,15*	*w3*	*w4,8,12,16*
min	*3.00*	*3.59*	*0.40*	*0.70*	*0.3*	*1.10*	*0.30*	*0.50*	*0.30*
max	*8.04*	*8.10*	*0.50*	*1.41*	*0.7*	*3.07*	*0.71*	*4.55*	*0.71*
	wlpa / wwpa	*wr1/wwpa*	*wr1/wlpa*	*wr2 / wwpa*	*wr2 / wlpa*	*wr3/wwpa*	*wr3/wlpa*	*wr1 min/ wr1 max*	*wr2 min/ wr2 max*
min	*1.00*	*0.17*	*0.14*	*0.17*	*0.14*	*0.13*	*0.07*	*0.83*	*0.65*
max	*1.30*	*0.31*	*0.31*	*0.63*	*0.56*	*0.45*	*0.93*	*1.00*	*1.00*

the second ring follow similar constraints. This means that one cannot have a house with a large patio and very narrow loggias and rooms, or the reverse. On the other hand, the depth of the third ring can vary wildly between 0.5 m and 4.55 m and does not seem to depend on the dimensions of the patio. This can be explained as the goal of the third ring is either to extend the rooms in the second ring, for which a small depth will do, or to create additional rooms that require minimum dimensions to become inhabitable.

Grammar

Due to space limitations, we only describe the grammar for generating the basic layout. This includes generating the basic pattern and introducing the entrance and the staircase. Not all the rules required for generating the 2nd floor are shown. The grammar was developed using weighted shapes in the product of algebras w12 · w22. Weights are used to represent different space uses.

Stage 1: Generate the basic pattern

The combined use of rules in this stage, generate all the possible basic patterns. Rule 1 introduces the initial shape on the first floor. Rules 2-7 apply to generate the patio and the first ring, whereas rules 8-12 introduce the 2nd ring. (Figure 4) Rules 31-34 permit diminishing the 2nd ring, (Figure 5) whereas Rules 35-38 allow the insertion of portions of the 3rd ring. (Figure 6) Figure 7 shows some of the rules to introduce the patio and the first ring on the second floor. The layout of the 2nd floor reflects to a larger extent the design of the first floor. For instance, the loggia might exists on the first floor and do not exist on the 2nd one, (Rules 43-46) however, when it exists, (Rules 39-42) it mirrors the loggia on the first floor.

Stage 2: Insert the entrance hall

Rules 13-19 (Figure 8) determine the shape and location of the entrance hall. It is shaped like a siphon to prevent the patio and other parts of the house to be seen by someone standing at the entrance door, thus protecting the privacy of the family. In most cases it is formed by two adjacent rectangular spaces forming an "L" shape connected through a door. In other cases, these spaces are merged into a single L-shaped space. In both cases, the entrance door and the inner passageway are located in each space but on parallel walls. The inner passageway usually gives access to the loggia, but when the house is small it might give direct access to the patio. The two spaces that form the entrance hall can be located on the first ring, (rules 18 and 19) or the outer one might be located on the third ring. (Rules 14 and 16) In some less common cases, it is formed by a

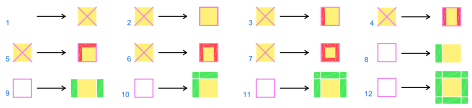


Figure 4
Rules for generating the basic pattern

Figure 5
Rules for diminishing 2nd ring

Figure 6
Rules for inserting the 3rd ring

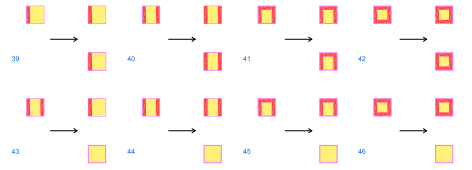


Figure 7
Rules for designing the patio and the first ring on the second floor.

Figure 8
Rules for inserting the entrance hall.

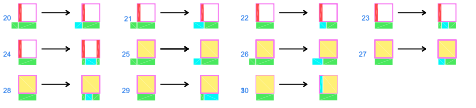


Figure 9
Rules for inserting the staircase.

single rectangular space but the entrance door and the inner passageway are located on perpendicular, adjacent walls for privacy. (Rules 13, 15, and 17)

Stage 3: Insert the staircase

Rules 20-30 (Figure 9) describe how to insert the staircase. There can be one or two staircases. When there is a second staircase, one is located next to the entrance. The staircases are located on the 2nd ring, either at the corner, (Rules 20-21, and 25-26) in which case they are articulated with the loggia when it exists, or on one the side. (Rules 22-24, and 27-29) The staircase can be located in the patio when the house is very small. (Rule 30) It also can be extended to the third ring too using one of the rules to add 3rd ring spaces. Depending of the height of the floors and on the dimensions of the staircase, the stairs can have one, two, three or four flights, thereby becoming I-shaped, U-shaped, C-shapes, or O-shaped.

Additional stages

The grammar includes additional stages for dividing the rings into rooms (Stage 4), for inserting openings (Stage 5) and for detailing the houses (Stage 6). Stage 4 includes not only rules for dividing the rings into rooms, but also rules for connecting rooms and assigning functions to them. None of these rules are shown in this article.

Derivation of the Dar Foundouk's basic pattern

The set of rules described above account not only for the generation of the houses in the corpus but also for new houses. As a way of illustration we show in Figure 10 the generation of the Dar Foundouk, the house in the corpus shown in Figure 2.

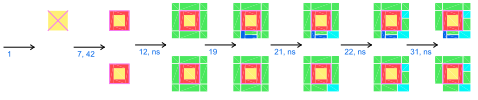


Figure 10
Derivation of Dar Foundouk. The number below the arrows identify the rule applied at each step of the derivation; ns means that one of the applied rules is not shown in this article.

Discussion and Conclusion

This paper presents a grammar to describe the formal structure of the Marrakech Medina houses. Since Stiny and Mitchell published the first housing grammar, the one for Palladian villas, (Stiny and Mitchell, 1978) a considerable number of other grammars has been published: Wright's prairie houses (Koning H, Eizenberg, 1981), Buffalo's bungalows (Downing and Flemming, 1981), Glen Murcutt's houses (Hanson and Radford, 1986), Queen Anne houses (Flemming, 1987), Taiwanese vernacular dwellings (Chiou and Krishnamurti, 1995), traditional Turkish houses (Cagdas, 1996), Turkish hayat houses (Colakoglu, 2005), and Siza's Malagueira houses (2005). The relative abundance of papers on housing grammars shows how this building type is so amenable to the development of grammars. The simplicity of the functional organization when compared to other building types, as well as the profusion of designs within particular styles and across different cultures makes it ideal for such a study.

However, despite this availability and the numerous studies on housing grammars, none has addressed how the design of the houses is articulated with the urban design. The issue is approached in the Malagueira grammar, but because the lot has a standard shape and the grammar has a top-down structure, any conflicts are implicitly avoided. In bottom-up grammars, which constitute the majority of housing grammars, the issue is far more complicated, as the generation of the detached house might cause the layout to extend beyond the lot's limits. In these grammars, the issue is avoided because generation proceeds without taken the lot into consideration. This is also the stance taken in our current case, as the paper is focused on revealing the formal structure of the houses. In previous grammars, one could always argue that lots can be drawn for houses, once these are generated, as they are larger than the houses and can be made to fit into an orthogonal urban grid. However, this approach would not solve the problem as houses are tight knit to the

urban fabric. A possible solution is to reverse the grammar. As it stands now, the houses are generated from the inside out, but it might be changed so that houses are generated from the outside in. This would require one to map lots shapes and sizes to housing basic patterns. As the study of houses in the corpus identified the maximum and minimum dimensions of the patio and the rings, the task might be cumbersome but can be accomplished. Future work will concentrate on this effort.

A detailed account of the historical and cultural background of the described research, as well as the computer implementation of the urban and housing grammars mentioned in this paper, including its incorporation into the GA-based generative system, will be presented elsewhere.

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