Shape Grammars as a support instrument for heritage safeguard planning

From a vernacular language to a contemporary materialization

Rúben Castro[1], José Nuno Beirão[2]
[1,2]Faculdade de Arquitetura da Universidade de Lisboa
[1]ruben.jr.castro@gmail.com [2]jnb@fa.ulisboa.pt

In this project we used the concept of shape grammars as a tool for understanding the vernacular heritage in the Moorish village of Aljezur in the South of Portugal, and subsequently use it to guide the planning rehabilitation and growth of the village. First, we inferred a grammar for describing the existent vernacular heritage, and based on it developed two other grammars suitable for the rehabilitation of pre-existences and the construction of new houses involving features that can harmoniously mingle with the heritage surroundings. This paper supports the use of shape grammars for the development of heritage safeguard strategies in historical urban agglomerates.

Keywords: *Shape Grammars, parametric, architectural heritage, safeguard, planning*

INTRODUCTION

In this article we intend to show how shape grammars can be an instrument used for the analysis and development of fully contextualized strategies concerning the safeguard of historical urban settlements, taking advantage of the ability of shape grammars of capturing the specific formal characteristics of such settlements.

Shape grammars are a mathematical formalism created by George Stiny and James Gips during the 70's (1972) to calculate with shape representations. This method consists of a shape generator system, resorting to a pre-defined set of rules applied to a finite group of shapes. Shape grammars can compute one, two or three dimensional shapes in a correspondent or larger dimensional space.

Based on the production system concept developed by the mathematician Emil Post and the generative grammar of Noam Chomsky of 1957, Stiny and Gips developed a similar system, which could be applied to geometric shapes, where Boolean operations or Euclidean transformations take the role of rules, that can be applied to those same shapes.

As a case study we chose Aljezur, a Moorish village in the south of Portugal, characterized by its vernacular houses, completely adapted to the steep topography and rough terrain. We chose this specific village because of the lack of regulations concerning the vernacular heritage, which combined with the constant pressure on the housing market caused by mass tourism on high season, are presently threatening the consistent harmonious historical urban set.

While creating the grammar, we took into consideration the definitions developed by Stiny (1980), and similar grammar based languages, such as Koning and Eizenberg's 'Language of the prairie' (1981) that focused on Frank Lloyd Wright's prairie houses, or the shape grammar created by Andrew I-Kang Li used for teaching the traditional architectural style of the Yingzao fashi (2001). Stiny's paper (1980) provides the mathematical definitions. The language of the prairie houses stood as reference for the demonstrated capacity of shape grammars for representing architectural languages and styles. The Yingzao fashi grammar supported the development of parallel grammars for the representation of a set of trihedral related architectural representations, namely, plan, section and elevation.

METHODOLOGY

For the elaboration of the grammar, we had to collect an exemplary study corpus able to represent the set of buildings composing our study, a set of typical vernacular houses from the historical core of Aljezur.

Aljezur is a Moorish village in the south of Portugal. It stands in the border of the Southwest Alentejo and Vicentine Coast Natural Park, close to the Atlantic coast. The small, singled pitched houses follow the typical winding Moorish streets until the castle on the hilltop, originally from the tenth century (Figure 1).

We collected information from several sources. Firstly, a literature review on Aljezur and the region's mountainside traditional construction, like the analysis of the survey made by the Portuguese Archi-

tects Association in the mid-fifties (1980), secondly we conducted local surveys on a specific selection of houses and finally a collection of photographs and graphic registers picturing Aljezur throughout the Twentieth century available from the book ALJEZUR 1869-1969 | Memórias (2018).

Afterwards we started the process of inferring a grammar that could be able to describe the study corpus - a 'vernacular grammar' - and subsequently adapting the same grammar, to the constraints defined by regulations and contemporary uses developing a 'preservation grammar' that could be used to support the refurbishment and requalification of the vernacular houses. After that, we tried to widen the constraints and respective variables in order to create a grammar suitable to support the creation and exploration of new houses involving more contemporary architectural values, but still harmoniously fitting the traditional language - a 'contemporary grammar'.

VERNACULAR GRAMMAR

For the development of the vernacular grammar, and following Li's Yingzao fashi grammar, we divided the rules into three parallel representations (plan, elevation and section) in a sequence of three rule sets:

1. Definition of inside spaces (living areas)
2. Definition of walls (built areas)
3. Integration into landscape

From the literature review and survey, we understood that a typical Aljezur house is a set of spaces linked by a single or double axis, parallel to the street and adjusted to the topography.

Figure 1
Panoramic view of Aljezur
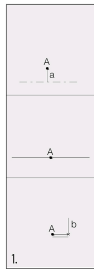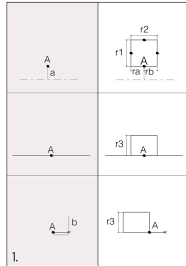
Figure 2
Initial shape
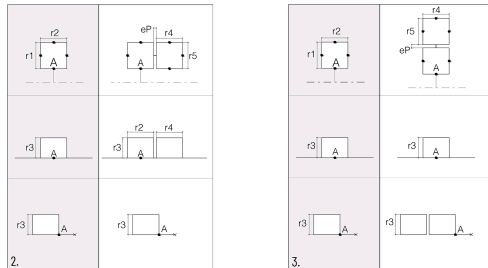

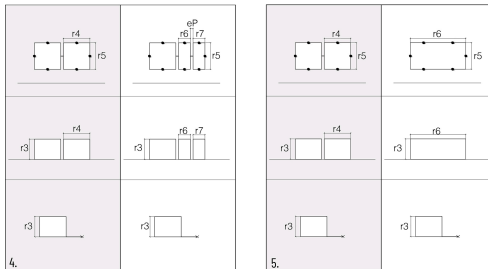Figure 3
Rule 1

Figure 4
Rules 2 and 3

Figure 5
Rules 4 and 5

Definition of inside spaces (living areas)

The initial shape consists of a point A, representing the main entrance of the house. This point is set at a variable distance (a) from the street limit, defined as 0,6≤a≤2, in which 0,6 corresponds to the width of the outside wall, as well as a variable vertical distance (b), which means that A may be higher or lower than the street used as reference (Figure 2).

While observing the study corpus, we could distinguish three functional zones. A living zone, a sleeping area, and a cooking area. These were the functional spaces defining the rural, poor, typical houses of farmers and land workers in this region.

Entrance Room. Every house starts with the placement of an "entrance room". This shape includes point A and three additional labels setting the linking points towards possible additional spaces. The entrance room is always defined as a living space (Figure 3). In this case, there is a proportion rate consisting of 0,8≤r2/r1≤2 and 2≤r3≤3,5. The relation between this space and A is set in a parametric way defined as ra=rb V ra≠rb, as long as ra≥0,6 and rb≥0,6 for structural reasons.

Axis growth. The following rules demonstrate how a typical Aljezur house is generated along a longitudinal axis (the axis parallel to the street and therefore presumably the axis along the lowest slope) by connecting spaces on linking points given by the previously generated labels. The generic rule is an addition rule which subtracts a label and adds a new space considering a wall as partition with a width of 50/60cm corresponding to the typical rammed earth wall (eP). In these new spaces, the proportion rule still applies, so that 2/3≤r4/r1≤2 and 1/2≤r5/r2≤1 (Figure 4).

Interior alignments. The following rules enable the subdivision of spaces or the union of two spaces along an alignment, permitting the necessary adjustments between functional areas (Figure 5). Rule 4 shows a compartmentation of a shape into two, so that r7=r5+eP+r6. Rule 5 allows a junction of two spaces into one, preserving the labels. In this case r4=r6+eP+r7, as long as r6=r7Vr6≠r7.

Definition of walls (built areas)

After the definition of the shapes that constitute our functional areas, we define the physical elements that create a house - the walls.

Rule 6 generates the self-supporting rammed earth walls. Considering a thickness of 60cm which corresponds to eP, rule 10 draws a polygon surrounding the spaces set before and defines the outside walls as well. The remaining labels representing linking points on the outside contour of the generated shape are replaced by the label **-** (Figure 6).

For the definition of windows and doors, we took into consideration the survey made on site, from which we defined the dimensions and attributes of these architectural objects, as well as their position on the main façade and proportions between transparent and opaque surfaces.

Once setting a table including the acceptable range for all variables, we defined the set of rules able to create elements such as windows, doors, or the possibility of erasing a label maintaining an opaque wall as many times found in the corpus (Figure 7). Here, the label **-** is used for the placement of these elements.

In this set of rules, the measurements of the elements were set according to the survey, so that:

- 7.a 0,6≤v1≤1,2m and 1,9≤v2≤2,2m.
- 7.b 0,45≤v1≤1m and 0,3≤v2≤1,2m.
- 7.d b≤1/3r3; 0,6≤v1≤1,2m and 1,9m≤v2≤2,2m.

Integration into landscape

After the definition of what we defined before as built areas, we established the relations that our shape maintains with its surroundings. In that manner, relevance is given to the way a typical Aljezur house is set on the steep terrain that characterizes this village.

Implantation into the topography. The topography is one of the main constraints on the formal development of these typical houses. Due to the steep slopes, the houses in Aljezur had to be built sometimes on a higher position than the street in which cases a front stair had to be added (Figure 8). We had
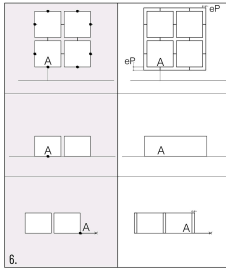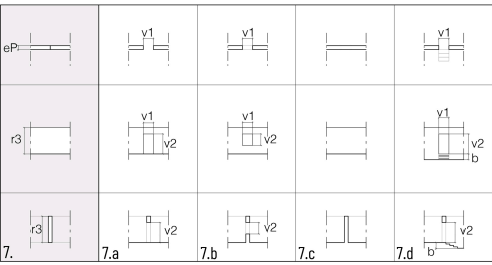

Figure 6
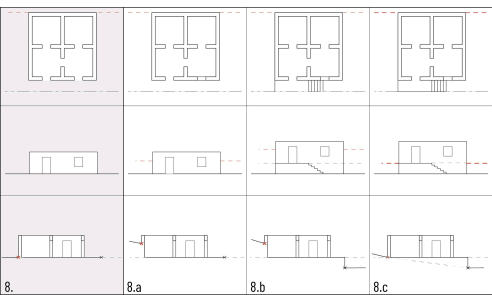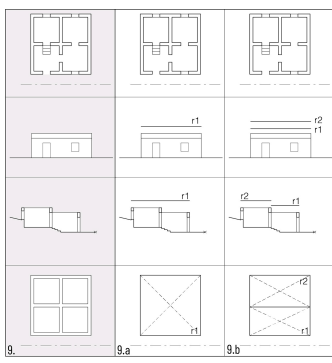Rule 6

Figure 7
Rule 7

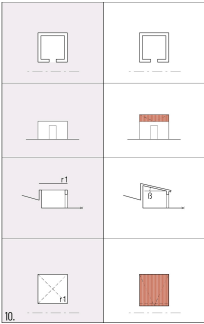Figure 8
Rule 8

Figure 9
Rule 9

Figure 10
Rule 10

Figure 11
Preservation
grammar - Rule 7.e
allows a removal of
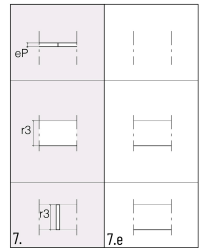an opaque element
(wall)

Figure 12
Preservation
grammar - Rule 9
specifies what
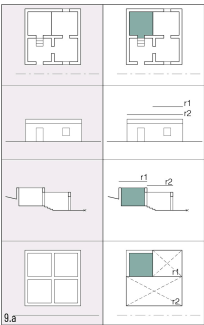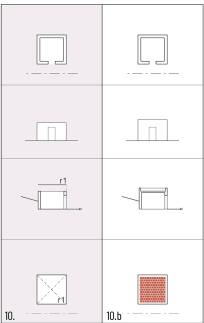happens when a
patio is inserted

Figure 13
Preservation
grammar - Rule 10
allows a placement
of a flat roof

set before as a basic implantation rule, a horizontal plane of reference, that contains both the edge of the street, as well as the limits of our shape.

Roof materialization. As part of its image, the single-pitched roof makes part of the architectural identity of Aljezur's typical houses. It is also possible to see some gabbled roofs as well but the single pitched roof dominates the settlement. The roofs are usually made out of traditional "canudo" roof tiles, perched on a wooden structure.

The rule 9 shows how the polygon that creates the roof is created (Figure 9). In this case, rule 9.a shows a creation of a mono-pitched roof, and rule 9.b shows a creation of a gabbled roof, taking into consideration the inside walls that can support the roof.

Rule 10 shows the materialization of the roof with the typical "canudo" roof tiles, here represented in red, and setting an angle ß, comprehended between 12º≤ß≤25º (Figure 10). The angles were extracted from the values observed in the study corpus.

TRANSFORMATION OF THE VERNACULAR GRAMMAR

After inferring the 'vernacular grammar', we were able to update it into a 'preservation grammar' that could answer contemporary architectural needs by displaying a new set of solutions inserted by new rules or changing the existing ones in order to obtain the needed flexibility for refurbishments that would adapt new contemporary spaces like toilets and bathrooms while keeping the vernacular formal characteristics.

For these changes we took as reference Knight's Transformations in design (1994) where the author explains how transformations in designs might be defined by changing existing rules, subtracting rules or adding new rules to the existing set. In the new grammar we included two new areas, the bathroom and the patio, as the design of new functional spaces was required.

Regarding the design of new buildings within the historical area and for inner space refurbishments (including the patio situations) we have widened the

range of the variables corresponding to wall widths, as well as parameters for the use of larger openings such as windows and doors, for improving lighting and ventilation.

Regarding roofs, we also introduced the possibility of designing flat roofs, inspired on the typical terrace roofs also found along the south coast of Portugal near the region of Aljezur.

After these transformations, we widen even more the range of the variables to create a broader grammar, suitable for creating new buildings, inspired on the vernacular housing but involving more contemporary features. This new grammar, the 'contemporary grammar', expanded the mass volume, widening the living areas and giving the possibility of raising two stories high houses, keeping new the functional areas inserted before - bathroom and patio.

However, a mass volume limit was given to control the 'volumetric grain' of the urban set within the morphologic pattern of the traditional settlement, hence controlling the image and integration of future urban growth. The historical part of the village presents some few buildings already with two stories providing additional information on what should be the acceptable limits of the generation of new houses. The control rule simply imposes a volume break rule above the given limit. The 'contemporary grammar', also allows for wider flexibility in the vertical parameters providing the generation of taller spaces or even the generation of a second floor.

In order to keep some tectonic features, the 'contemporary grammar' combines traditional construction elements like rammed earth walls with contemporary construction techniques.

SAFEGUARD PLANNING WITH SHAPE GRAMMARS

Aljezur provides an interesting territory to apply grammar based methods as strategic heritage safeguard planning. The urban tissue of Aljezur is composed of two distinct areas: the old town built on the hillside, and the new town separated by a river and
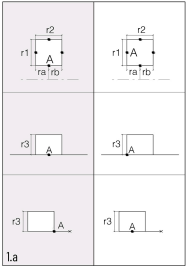

Figure 14
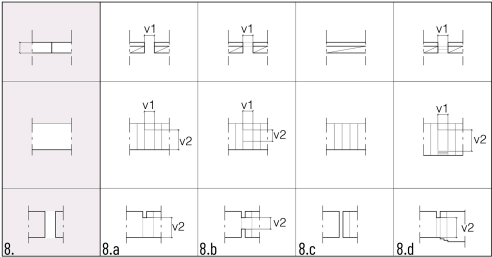Contemporary grammar - New Rule 1.a, which allows the rotation of the label A

Figure 15
Contemporary grammar - New Rule 8, Which allows different widths of eP: 0,6≤eP≤1,2
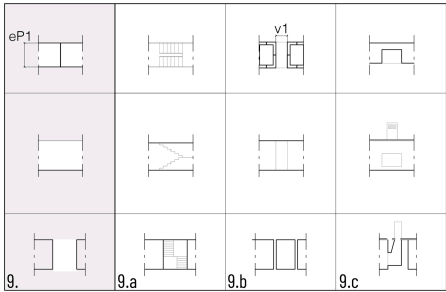

Figure 16
Contemporary grammar - New rule 9, which allows different widths of eP: 1,2≤eP≤2,4

lowland meadows on the east side of the river. The latter area was initiated in the 19th century and has been since the area where the main recent developments have been made. The visual relationship between the two parts is wide and free of visual obstacles. The old town built on the steep hillside is a thousand-year settlement with very characteristic architectural heritage which should be unquestionably protected, not only because of its consistent and typical architectural morphology, but also because it is the best example of the kind, and only found in this region of Portugal.

However, any serious preservation action should consider the visual relationship between the two parts of the town guaranteeing essentially that new developments do not destroy the aesthetical equilibrium of the settlement and the visual relation between the two parts. Therefore, the previously given grammars provide strategic answers for the development of a heritage safeguard plan, namely: (1) the 'vernacular grammar' provides a morpho-typological description of the traditional architecture characterizing the historical core of Aljezur; (2) the 'preservation grammar' provides the rules for the acceptable design space for the preservation and rehabilitation of the historical core; and (3) the 'contemporary grammar' adapts the 'preservation grammar' to a wider solution space applicable in the new town area, and allowing a more modern discourse while keeping a minimum number of features which are capable of maintaining a harmonious visual relation between old and new town areas. The grammars do not only provide regulations for the plan as they also provide through their generative properties examples of a good practice (Figures 17 and 18 shows some of those examples generated by the grammars).

DISCUSSION

Aljezur typical houses are a reflection of the times passed, and a living memory for the ones who live in them. Here we found a creative opportunity to grab what we may think as not especially relevant in terms of architectural value, and use it as an inspiration for the creation of new, contemporary houses.
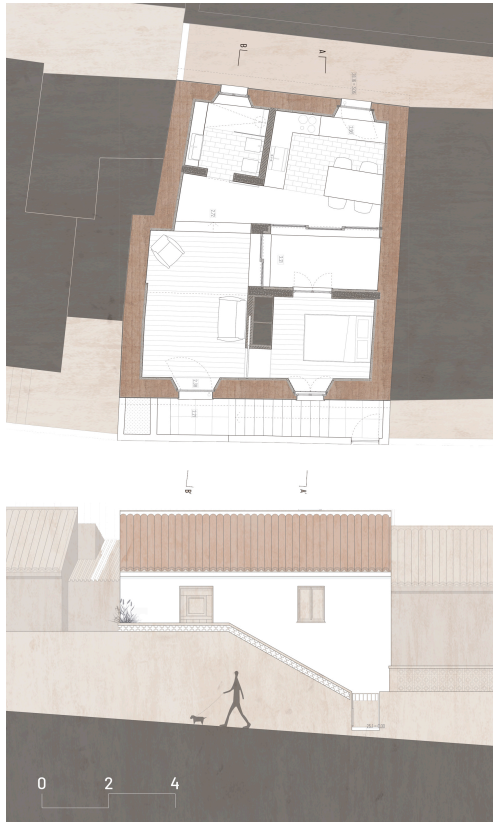
proach may combine an ontology of the representation components expressing a taxonomy of the representation and a topology of relations. Rules computing the topological relations could then be expressed by means of a graph grammar. To be developed as future work.

As shape grammars are able to capture architectural languages, they may proof to be a useful instrument for supporting the development of heritage safeguard regulations and guide growth while respecting the morphological heritage context promoting harmonious integration even involving new urban extensions.

REFERENCES

Castro, R 2018, *Gramáticas da forma como instrumento para a preservação da imagem patrimonial*, Master's Thesis, FAULisboa

Gonçalves, José [et al.] (eds) 2018, *Aljezur 1969-1969 | Memórias*, Câmara Municipal de Aljezur, Aljezur

Knight, T 1989, 'Color grammars: Designing with lines and colors', *Environment and Planning B: Planning and Design*, 16(4), pp. 417-449

Knight, T 1994, *Transformations in Design*, Cambridge University Press, Cambridge

Koning, H and Eizenberg, J 1981, 'The language of the prairie: Frank Lloyd Wright's prairie houses', *Environment and Planning B: Planning and Design*, 8, pp. 295-323

Li, Al 2001, *A shape grammar for teaching the architectural style of the Yingzao fashi*, Ph.D. Thesis, MIT

Associação dos arquitectos portugueses, AAP (eds) 1980, *Arquitectura Popular em Portugal*, Associação dos arquitectos portugueses, Lisbon

Stiny, G 1980, 'Introduction to shape and shape grammars', *Environment and Planning B: Planning and Design*, 7, pp. 343-351

Stiny, G and Gips, J IFIP Congress. 71. 1460-1465 'Shape Grammars and the Generative Specification of Painting and Sculpture', *IFIP Congress 1971*, pp. 1460-1465

Stiny, G and Mitchell, W 1978, 'The Palladian Grammar', *Environment and Planning B: Planning and Design*, 5, pp. 5-18

Shape grammars, and parametric shape grammars were the tool used to understand how these elements are spatially arranged and built. It helped us to understand what we called invariables, characteristics inherent to these architectural types. With the information provided by the grammar, we were able to deconstruct original historical types, and complete them with new elements, and also develop a contemporary grammar, inspired in the past but looking forward. In this way, rules for future developments become conscious and explicit.

Technically speaking, the grammar can still be improved by introducing a semantic structure controlling the relations between spaces. Such ap-