Re-inventing ceramic tiles

Using shape grammars as a generative method and the impact on design methodology

Deborah Benrós[1], Sara Eloy[2], José Pinto Duarte[3]

[1] University College London
d.benros.09@ucl.ac.uk

[2] Lisbon University Institute
sara.eloy@iscte-iul.pt

[3] University of Lisbon
jduarte@fa.ulisboa.pt

Abstract. The following paper describes the process and results achieved with the workshop entitled 'Re-inventing Portuguese ceramic tiles' reflecting on design methodology and design teaching.
Workshop participants were invited to rethink ceramic tile patterns developing a different process which used shape grammars as a generative system. Each participant group developed a three stage task using shape grammars principles and methodology.
The preliminary results the work developed are of particular relevance in shape grammar research: firstly shape grammar formulae does not constitute an intuitive process to most creative designers which are often trained to design singular solutions for a specific problem, secondly more than one operative shape grammar can be formulated to represent the same corpus of solutions and lastly the generative potential of grammars transcends the normal capacities of the original grammarist aiding in design exploration and enlarging the corpus of feasible solutions.
This paper also reflects on the impact of shape grammars as a design methodology.

Keywords: Shape grammar, patterns, ceramic tiles, 2d, 3d

1 Introduction

Previous studies on shape grammars in teaching focused on how these can be used as an effective design methodology. In several academic institutions shape grammars are part of the curriculum and are being taught to young designers. As examples Massachusetts Institute of Technology, University of Lisbon, University College London and others. Most of these programs offer either undergraduate or post

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graduate modules where grammars are taught using a practical approach. In addition they have been showcased in workshops to test design processes and design languages [1].
Similarly to other ruled based systems they confer a level of systemization and structure required to efficient and consistent designs. They also allow for an efficient way of testing and exploring design solutions or simply providing diversity and maintaining consistency through mass customization processes whilst avoiding an important problem designers face - fixation.

This paper focuses on the results of the workshop 'Re-inventing Portuguese ceramic tiles: Using shape grammars as generative method'. The workshop took place in Porto University School of Architecture in April 2013, counted with the contribution of 10 participants, most with no previous experience or exposure to shape grammar theory.
The aims were looking at Portuguese traditional ceramic tiles design techniques as a starting point to re-invent patterns and textures considering the use of different design. Ceramic tiles occupy a particularly important place in the overall panorama of Portuguese artistic creativity and have been use in Portugal since the 15th century without interruptions until today. In the 50's ceramic tiles had a revival and several artists were called to produce artistic panels both to buildings and urban spaces (see example in **Fig. 8**). New design processes and manufacture techniques may be use nowadays to innovate in this well recognized Portuguese industries introducing new designs and exploring the possibilities of tridimensionality and the use of other materials.

The main goal was to use shape grammars as a design methodology for the creation of bi-dimensional ceramic tile patterns. Shape grammars were also used to analyze and describe the designs and produce new solutions. The workshop was carried out though the extent of a day, in a total of 8 hours and it was divided into 4 mains tasks:

1. Introduction to shape grammars, shape rule formulation and derivation process
2. Creation of a new shape grammar to generate ceramic tiles patterns
3. Rule extraction and shape grammar inference
4. Creation of shape rules to convert a bi-dimensional shape grammar to a three dimensional

The following paper will focus on the use of shape grammars as a design methodology and its benefits on design creation focusing tasks 1 to 3. It is organized into four sections. Respectively: precedents, methodology, results and conclusion with discussion on findings and future work.

2 Precedents

Shape grammars can be defined as a formulation composed by geometric shape rules or transformations that once applied recursively and ordered in successive steps can produce a family of designs that share the same design principles, features or style [2].

It proved to be an efficient way to describe architectural styles, design and even painting styles.

The first experiment on an architectural example was the Palladian grammar [3]. The grammar reproduced bi-dimensional villas floor plans and was the first real implementation of the shape grammar theory into a design context. Another important precedent was the Kindergarten grammar [4]. This grammar encoded a set of limited shapes lexicon provided in the children board game - composed by building blocks. This work reflected on the different spatial relations between the blocks provided and in basic additive rules to describe compositions. This work inspired the methodology used to depict shape grammars and illustrate shapes.

Another significant work was the study developed using shape grammars as a way to describe Islamic ceramic patterns [5]. This study dwells on the wealth of patterns provided by Islamic geometric tiles and proposes a generative design methodology to recreate these (**Fig. 1**). This grammar does not attempt to replicate the designer role by replicating the design process originally used. Instead it attempts to recreate patterns by shape emergence. To do so, different Islamic patterns were studied as case study and its inherent shapes analyzed. Sixteen different shapes were identified as lexicon in different compositions. All of these polygonal present diverse shapes. Most of them are regular polygons based on bi-dimensional designs. Among these shapes one can identify stars, wedges, squares, pentagons, arrows, and hexagons. Jowers and Prats [5] came up with a methodology that could potentiate the range of designs desired. The different patterns were observed presenting a vertical, horizontal or a 45 degrees rotation orientation. The issue of symmetry is closely related to the question of repetition. Taking this into account Jowers and Prats [5] used the square tile shape as a starting point and selected only a half portion. This half portion was selected through the main tile diagonal which could be easily mirrored. The obtained shape is a square triangle with a vertical, a horizontal and a main diagonal border. These boundaries became the directors of the whole pattern design. The grid is then placed as an auxiliary method to the design. The grid lines are then traced parallel to the border of the tile triangle forming a diagrid. This diagrid is constituted of construction lines represented graphically with dotted lines. Labels are placed between dotted lines and mostly on its endpoints. These labels, in the shape of dots, helped identifying the endpoints. By filling between the dots a continuous line is generated allowing for changes of direction and configuration. This grammar showcases a similar formulation based on a grid.

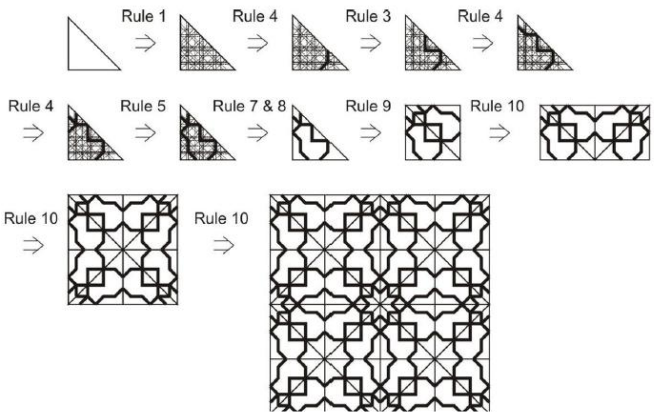

Fig. 1. A derivation of a design solution done by the generative design methodology created by Jowers and Prats [5] to recreate Islamic geometric pattern. [5, p.47]

It also shows a different type of grid, a non-orthogonal. It sums successfully the potential of shape grammar formulation and its generative power even when using a limited set of rules as ten which allows an unrestricted set of examples and a significant number of possible design solutions. This grammar was shown to the workshop participants as an example and reference.

3 Methodology

The workshop was targeted to both experienced and non-proficient grammar users. Shape grammars conferred an alternative method to describe and generate design to the participants as well as a way to transform the design process into a more efficient system. To the organizers the workshop provided a controlled environment where theories on shape grammar inference process could be tested using real designers and a mix of experienced and not experienced grammarians.
In this research the term ‘designer’ is used for the ones that design and ‘grammarian’ for the ones that research on shape grammars. A third group of ‘grammarian designers’ is used to refer to the designers that use shape grammar systems in their design projects and a fourth group, ‘traditional designers’, to refer to the designers that don’t use grammars at all.

In order to achieve the desired outcome and provide significant answers was important to provide a basic knowledge foundation regarding the basic shape grammar formalism, shape grammar graphical representation and the generation process commonly known as derivation. With this in mind an introduction and examples were provided. This constituted the first stage. The second stage encompassed an introductory task in order to familiarize participants with grammar methodology. Groups of 2 to 3 participants were formed and each team was asked to develop a brand new shape grammar. This shape grammar had to be graphically

represented through a set of shape rules. In addition they had to provide operable design solutions developed using the grammar originally created.
For this first task some conditions were pre-set:

1. Each team had to generate a complete new shape grammar to create bi-dimensional ceramic tiles patterns
2. A lexicon of shapes was provided, participants had to exclusively use these shapes for the grammar formulation
3. The set of design rules had to be graphically illustrated
4. Design solutions as outcome of the shape grammar had to be provided

In order to facilitate the experience the lexicon of shapes was provided using three dimensional solids. This proved to be a successful method of fully grasping shape grammars procedures. Usual grammar classes often recur to sketching and paper tracing. Experience shows that this often limits the notion of embedding and the full spatial experience of a shape. The hand scale solids allowed a more tactile experience with a more significant spatial allowance and a way to develop both patterns and shape relations in a back and forth continuous way between physical tiles and sketching.

The supplied lexicon of shapes combined as shown in the **Fig. 2** and **Fig. 3**: 100x100mm yellow square, 100x100x140 mm yellow triangle, 100x50 mm yellow rectangle, 100x25 mm yellow rectangle, 50x50 mm orange square, 50x50x70 mm orange triangle, 100x50 mm orange rectangle, 100x25 mm orange rectangle. The shapes were provided as MDF cut-outs of colored boards. Each team was provided with a large number of samples, enough to illustrate rules and generate design solutions.

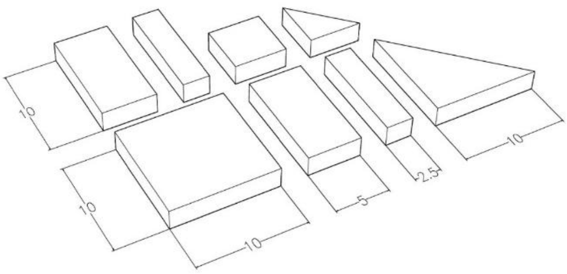

Fig. 2. Supplied lexicon of 8 shapes

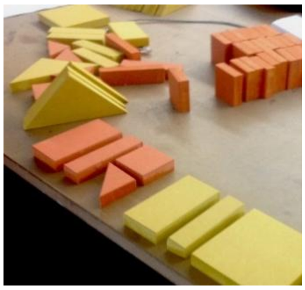

Fig. 3. Supplied lexicon of 8 shapes

Often these simple spatial relations could be captured by additive shape rules. To each shape another was added or combined into a specific position to create a new situation.

Most groups recorded those rules by simple sketches. A small group of participants illustrated the rules using the shapes provided. Once these were identified and selected, the teams combined the different groups of shapes to develop a pattern. In some of the grammars provided there were a clear distinction between shape rules to describe spatial relations and rules to generate a pattern or a tiling matrix.

Similarly to the work of Prats and Powers [5] on ceramic Islamic patterns, which served as a reference for the workshop, most rules were clearly segregated between design rules and tiling rules. There were however exceptions where patterns and tilling patterns were coincident. No difficulties were encountered by the participants with the grammar formulae or standard representation.

The results of this experiment were diverse in theme and in outcome. Different groups opted either by bi-dimensional planar patterns or by exploring three dimensionality of the solids provided playing with voids, rotations and different solid thicknesses.

Shape grammar clearly assisted as creativity aider, helping the designers to generate rich and diverse solutions. Amongst the different groups diverse solutions and grammars were originated despite the initial limitations and the pre-set lexicon. The provision of shape rules did not inhibited design and the creators did not feel limited by the restrictions imposed. Shape grammar as a design methodology for tile patterns proved successful.

Illustrated below is the work of team A (**Fig. 4** and
Fig. 6) and team B (

Fig. 5 and **Fig. 7**). These two teams are presented here as a sample of the work generated in the course of the workshop. They are representative of the variety of shape rules and patterns created given a fixed number and range of shapes as lexicon. The approaches followed are quite distinct although the starting point was similar. Both teams starting by experimenting different spatial relationships with the shapes provided. Team A was interested in providing linear bands that framed the composition vertically whilst team B was interested in the concept of void versus volume.

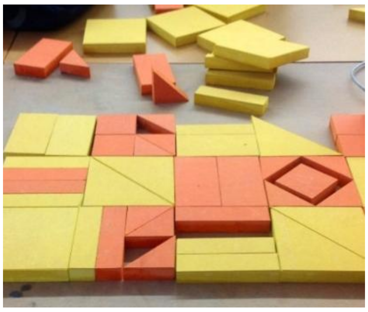

Fig. 4. (left) Team A pattern

Fig. 5. (right) Team B pattern

Team A shape grammar can be recreated using an addition strategy where squares and rectangles are juxtaposed to form bands. The pattern can be developed using mostly addition rules. This is replicated in the derivation diagram in

Fig. 6, where clearly 70% of the derivation consists of addition. Furthermore the shape rules provided that consist the grammar are in its majority addition rules followed by subdivision rules. **Fig. 4** illustrates the real design solution generated in the workshop and later described in

Fig. 6. Team B's pattern is pictured in

Fig. 5. This pattern explores the notion of square repetition that is commonly used in ceramic tiles. Even though the basic square repetition is present the pattern and its grammar allow for great diversity and the omission of repetition. Team B showcased a very different strategy where both addition and subdivision rules occupy a place of relevance in the grammar. Deletion rules were also implemented to originate voids in the pattern. Both teams and their patterns allow a great level of liberty and potentiate the omission of repetition whilst playing with a limited corpus of shapes. This experiment proved the creative potential of shape grammars when applied to bi-dimensional patterns and with the same vocabulary of shapes.

The second task consisted on the replication of a common task developed by grammarians, the rule inference. Traditionally shape grammars are efficient methods of describing design languages and design families. The first design application of shape grammars was the recreation of Palladian villas [3]. This work aimed at identifying the key design principles of the extensive body of work of 'domestic' Palladian architecture, inferred design rules and created a shape grammar. This shape grammar was a powerful tool that encoded expert knowledge retained in the geometries, proportions and spatial relations originally used. It also allowed the recreation of the original corpus of designs and the generation of a new corpus that followed the principles of the family of solutions. Not much has been discussed about the inference process even though many authors used it in the past to recreate Prairie [7] and Malagueira houses [8], Wren city churches [9], Taiwanese houses [10], to name a few.

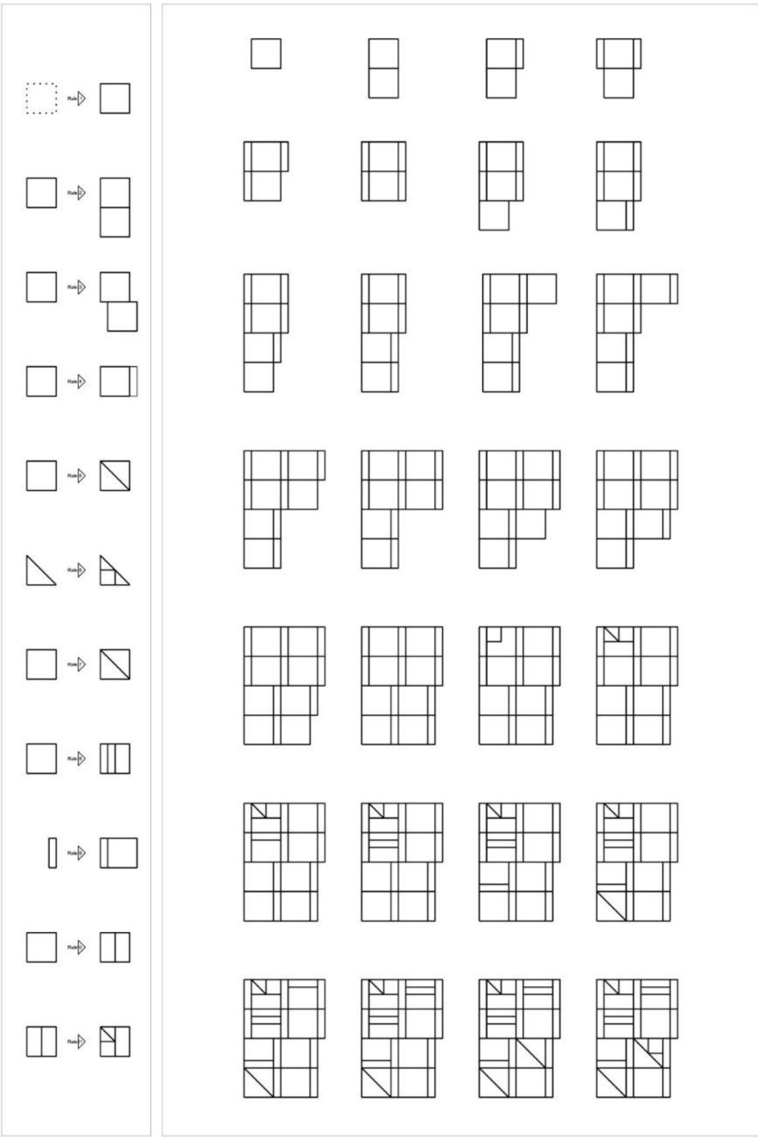

Fig. 6. Team A shape grammar and derivation

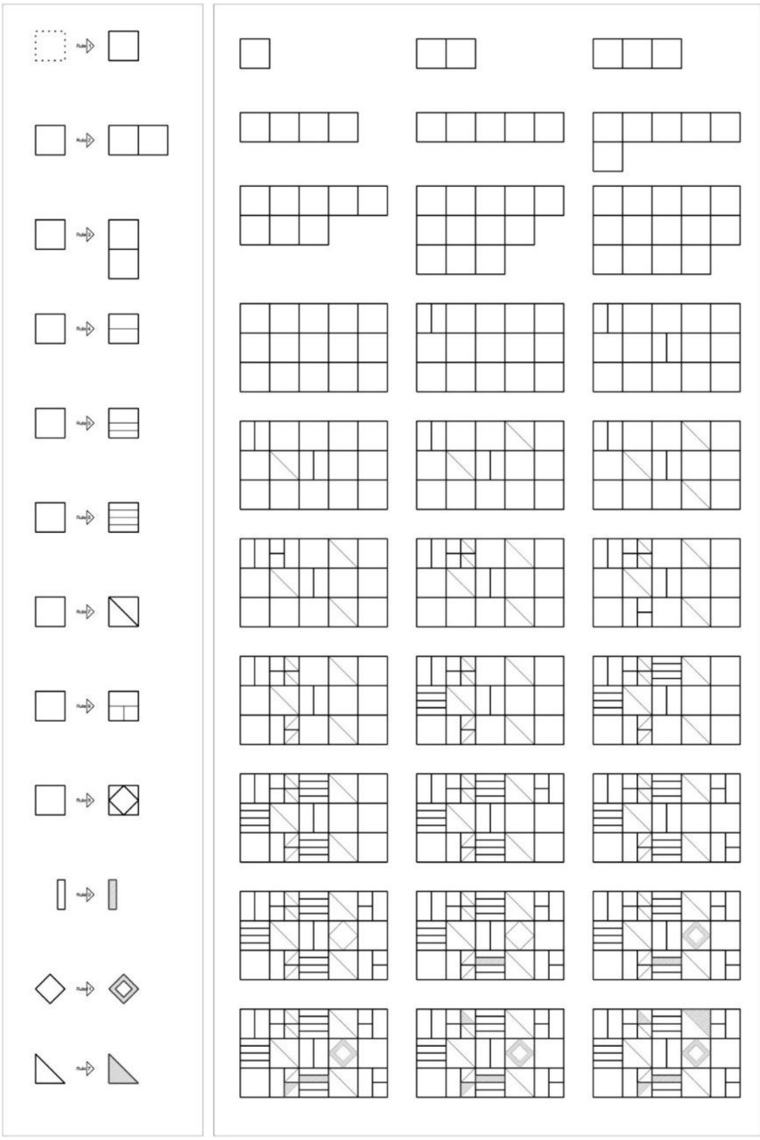

Fig. 7. Team B shape grammar and derivation

Nevertheless the inference process is an intensive and intuitive trial error process. The automation of the inference has been attempted and tested in works such as the city modelling project [6] and in the car design industry [11].

The second task had an undisclosed goal, to test the inference process put into place by different participants. It allowed testing how different participants would infer shape rules given a same design example. Each participant team was provided images containing ceramic tiles' patterns. Each group was invited to analyze the pattern and generate a grammar that would efficiently replicate the family of patterns as illustrated in the picture (**Fig. 8**). The same image was provided to two of the participant teams for comparison purposes. **Fig. 8** shows one of the patterns provided, and a diagram with the dissected pattern. Intentionally this was the pattern that was tested simultaneously by the two teams.

Fig. 8. (left) Ceramic tiles pattern as provided to Team A and B (Portuguese artist Maria Keil)

Fig. 9. (right) One of the teams inferring shape rules and its graphical representation**.**

Generally in literature to each grammar is attached a specific language. Moreover most grammars were developed to describe a specific style. Once this has been achieved grammarists will focus in other languages. To the extent of our knowledge no substitute grammar has been published with the aim of proposing a valid alternative to a grammar specifically created to replicate languages with the exception of previous work on the Alternative Palladian grammar [12]. This task was important to test how different grammarian designers would propose rules to describe the same body of work.

Using the first task as a reference most groups started by identifying the lexicon used in the images provided. This informal task was not formally suggested but was consistently used by all groups as a way to subdivide the problem into manageable items (

Fig. 9). The teams were encouraged to disregard the tilling matrix and its basic square shape and focus on the pattern geometry.

Team A identified all shapes/colors recurrent in the pattern. At a second stage the different combinations and spatial relations between shapes were studied and simply sketched. From the various possibilities team A selected the feasible rules hypothesis and ruled out redundant rules. Additional rules were also created to combine in big scale square matrix different spatial relations.

Simple derivation sketches were carried out to test the grammar and recreate the original pattern as shown in **Fig. 8**. The grammar created can be classified according to Knight as unrestrictive type of grammar since also allows an array of solutions that follow the design rules created but do not necessarily relate with the original solution requiring a level of intelligent use to generate the original design [13]. It also proposes an extensive group of shape rules, as shown in the diagram above (**Fig. 10**).

Team B followed a similar initial methodology. Also focused on the different shapes and spatial relations to ultimately attempt to rationalize all the examples encountered/identified. To the extensive list of shapes colors and spatial relations identified, they identified a standard basic shape. The team observed that most of the geometries encountered could be described by a diagonally split square colored by contrasting dark/light colors. The split square and its division line were then easily represented by square with an inner dot label. The position of the label near one of the vertexes described the tone contrast and direction of split. From this point simple transformation rules were replicated were to a basic shape another one was added with a specific rotation or circumstance as allowed by the pattern. This grammar proved to be elegant, compact and descriptive. It allowed the design of the original corpus and other solutions easily identified as family related solutions (as shown in **Fig. 11**).

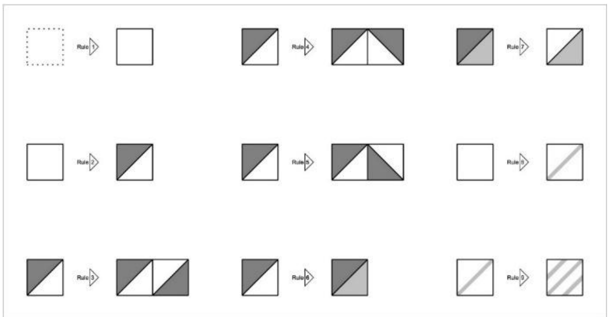

Fig. 10. Team A inferred shape grammar

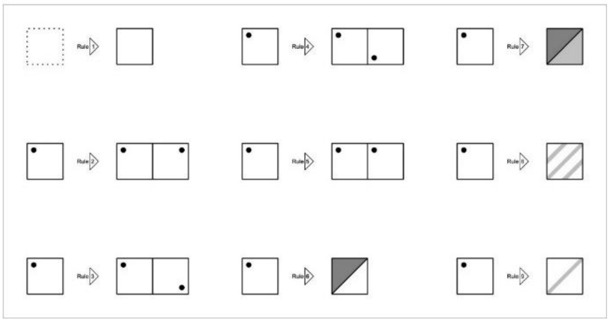

Fig. 11. Team B inferred shape grammar

Fig. 12. Design created by the grammar of both Team A and B

Team A showed a deep concern by the shapes and patterns to be illustrated and had more difficulties exploring the shape grammar methodology resulting into a more extensive set of rules. Team B embraced shape grammars formulae and experimented with labels which resulted into a more elegant concise grammar. Nevertheless, both grammars proposed by team A and B are feasible and respond to the problem formulated as shown in **Fig. 12** illustrating the pattern that originated the grammar and a new one that was produced with the same grammar.

4 Results

The results achieved by team A and team B unraveled important issues that contribute to the overall knowledge about shape grammars and generative methods in designs:

1. Shape grammar methodology allows for more than one grammar to describe the same body of results or languages. Different grammars may generate the same corpus of design but also have the potential to generate different solutions.
2. Restrictive and descriptive grammars allow for a level of precision useful to replicate an existing body of work.
3. Unrestrictive grammars allow for useful design exploration by setting specific design principles but not over restricting outcomes.
4. Descriptive shape grammars result into an extensive set of rules.
5. The use of labels can aid in the optimization of grammars and result in an elegant, concise and intelligent grammar.
6. More than one grammar can be feasible responding to the problem formulated.

Results also showed that the use of shape grammars both for creating traditional and new patterns of ceramic tiles is a feasible and useful design strategy that, with the use of digital tools to enhance mass customization, enable the creation of alternative design, exploring the graphic richness of this type of artistic work.

5 Conclusion

Shape grammars provide an efficient methodology for design. This has been arguably one of the biggest controversies between traditional designers and grammarians and grammarian designers. Traditional designers overlook shape grammars as an easy method to allow plagiarism or 'pastiche' design and fail to see the real benefit of the implementation of grammars in design methodology, design teaching and practice.

The workshop organized and discussed had two major goals, to test the application of shape grammars in design methodology and to analyze how the inference process of grammar rules can be described and processed efficiently.

For the workshop participants the grammar methodology was clearly a useful method that could be further applied in design. Grammars provide undoubtedly a good alternative as design process potentiating creativity and the exploration of feasible design solutions. As a rule based system it is a successful method to allow for the creation of diverse corpus of solutions.

For the workshop organizers it allowed to test the theory that more than one grammar can be employed to describe the same body of work. It also proved that shape grammars do not require a deep and extensive know-how to be employed and can, contrary to some sources, be easily taught and applied.

The previous sections described two main tasks developed during the workshop 'Re-inventing Portuguese ceramic tiles: Using shape grammars as generative method': the development of a new design grammar and the inference of a grammar from a given example. The first task aimed at proving the efficiency of grammars as design method for both teaching and in practice. The second task tested and analyzed the inference process. Both tasks proved useful as learning tools for the proficient use of grammars.

The first task was based on a limited set of predefined variables, the lexicon. Despite the limitations the participants were able to generate 5 distinct grammars all using the same limited set of shapes as lexicon. From these grammars a significant number of shape rules were developed generating different solutions. The experience lasted 2 hours, used inexperienced participants and outcome showcased diversity and design creativity. The results prove the potential of shape grammars as design tools.

The second task tested the rule extraction process. This task helped prove that two distinct grammars can replicate the same design corpus whilst allowing an additional corpus of different design solutions. It also showed that restrictive grammars are useful in describing particular design languages but might restrict the production of novel designs. Whilst unrestrictive grammars might fail in precision but potentiate design exploration.

These findings consubstantiate the usefulness of the grammar methodology.

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