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AN ALTERNATIVE PALLADIAN SHAPE GRAMMAR

A subdivision grammar for Palladian villas

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Abstract. This paper describes a shape grammar that recreates Palladio's villas. A Palladian grammar was previously proposed by Stiny and Mitchell. However, this alternative grammar uses different parametric shape rules and methodology to test the hypothesis that different grammars can generate the same corpus of designs. The formalism is then implemented using a computerised design tool. The grammar includes subdivision rules that allow for a more economical formulation. The project is part of wider research aimed at formulating a generic housing grammar.

Keywords. Shape grammar; design rules; housing grammar.

1. Introduction

This research paper describes the methodology used to recreate Palladio's design signature using a formalism called shape grammar. Stiny and Mitchell (1978a) illustrated the range of shape grammar and its first architectural applications. Thiswork replicates what was presented forty years ago, using an alternative grammar and a computerised tool. The concept was applied to urban grammars to develop a partial generic urban grammar (Beirão et al. 2011).The novelty of this research lies in the hypothesis that more than one grammar can generate the same design solutions and if two separate sets of shape rules can produce the same solutions, this can be illustrated by generic rules enabling a generic grammar seems feasible.

The notion of grammars was widely discussed by the linguist Chomsky (Chomsky 1957). He describes how different languages with different roots encapsulate an innate sense of grammar and phrase formulation. The idea of a universal grammar explains these innate formulations.Subsequently, the notion of grammar was introduced into the field of geometry and algebra (Stiny 1975, 1980, 2011). A shape grammar is a structured formalism that incorporates a limited number of shape rules to describe geometric operations. These consist of an initial and a final stage, with a transformation, or geometric operation occurring between them. Combining different shape rules and ordering them into a shape grammar enables design styles to be recreated, such as the grammars for the Prairie houses (Koning and Eizenberg 1981), Siza's Malagueira houses (Duarte 2001), Ice-Ray Lattices (Stiny 1977) and the De Stjil paintings (Knight 1989).

According to Knight, there are three types of shape grammar processes: grid, addition and subdivision (Knight 1999). Grid grammars propose design generation based on a matrix. The design is derived from the grid using cell merging and subdivision processes. The original Palladian Grammar used a grid process to address the rectangular floor plan. In subdivision the solution is achieved through a succession of divisions and self-contained.

This alternative grammar uses a subdivision process. The justification for this is threefold: firstly, it represents a more intuitive way of designing, secondly, it allows for fewer shape rules and is more economical, easier to use, and thirdly it proposes a different process, thus proving that two distinct formulations can generate same results. The rule extraction process was based on observation of different existing villas, examining each floor plan, number of rooms, proportions, geometries, spatial adjacencies and communicating rooms. The layout of the floor plan for each villa uses 9 basic rules in contrast with the 25 used in the original grammar and all the shape rules have a parametric formulation. The initial rules define the boundary setting, whilst the rules that follow propose subdivisions. Other rules allow for the merging of consecutive cells by erasing borders. The design is completed by allocating centrally aligned openings in accordance with the original specifications (Palladio 1997).

Functions were not addressed in the original grammar, but were incorporated in this study. It was possible to identify the functions in unlabelled sixteenth century villas by observing spatial adjacencies, using comparison as a method and taking proportion, shape and area into account. Notions of shape syntax integration and segregation were also considered (Hiller and Hanson 1984).

A computerised tool was created to provide non-shape grammar users a visual platform for exploring design. The script is easily accessible to CAD users and allows for real time 2D/3D design generation and visualisation.

Previous studies have proved that an extensive corpus of designs can be produced from limited design rules (Stiny and Mitchell 1978b). The original grammar allowed for the production of 220 solutions for grids of 5×3 cells. A generic grammar would allow for the design of more than one type of signature style and an extended corpus of solutions.

The relevance of this study is related to the wider aim of proposing a generic grammar for housing. Studies on grammars have been limited to illustrating specific styles but no two different grammars and rules sets have ever produced overlapping corpus. It is believed that there is more than one method for obtaining a grammar that incorporates style, confirming the hypothesis of shape grammars as broad formulations that can illustrate style.

This paper is organised into 6 sections. Section 2 explores the grammar formulation, whilst Section 3 describes the shape rules; 4 and 5 focus on the villa derivation and computer implementation respectively. The final section contains the conclusion and comments on the results.

2. Shape grammar formulation

A top-down approach was used in which the design process begins with the overall shape and evolves to further detailing. The self-contained boundary is set and a series of tasks are carried out to refine the design. The starting was the exploration previously inferred grammars. Using Knight's grammar classification, a case study was selected, comprising grid (Palladio), addition (Wright) and subdivision (Siza). The grammar structures were compared and the results led to a proposal that addressed the basics of housing design. The Palladian designed villas were studied and their generic features. A rectangular envelope constitutes the boundary and the villas are composed of a raised ground floor which contains the main social areas. A lower level ground floor contains the service areas, pantries, kitchens and servants quarters. The upper level contains living and bedroom areas for the house owner and family. The main floor is raised by steps and has more headroom, extending to the façade. This is the only floor plan usually illustrated and has been extensively studied by art historians so it is easily identified. The symmetry between the east and west wings is created by the north/south axis. The larger core area in the geometric centre of the construction has a complex shape that is the result of cell merging. Windows (like the eyes in the human face) are arranged in even numbers whereas doors are centred and arranged in uneven numbers.

The main entrance is defined by a portico which enhances classical features of the façade typical of Renaissance architecture. The preferred proportions for the design of rooms, service and circulation areas are usually rectangular or oblong spaces with 1/2, 1/3, 1/4 ratios, whereas the main rooms are square, regular polygons, or rectangular areas with a 2/3 ratio (a proportion frequently adopted by established architects such as Aalto and Siza). The Malcontenta, Angarano, Badoer, Zeno, Pisani, Emo, Sarraceno, Ragona and Polana villas were used as case studies for rule extraction. Except villa Angarano, they all have a 3×5 grid. Both the original scheme (Figure 1) and the alternative (Figure 2) propose 8 design stages. The initial stage sets the rectangular boundary. The second stage encompasses subdivision rules. It groups together the two subdivision shape rules for horizontal and vertical formulation. Vertical subdivision is performed in accordance with the symmetrical nature of the design, introducing two division lines. Stage Four, which involves wall thickening, makes the basic outline two-dimensional. This stage deviates from the original grammar since in the latter the wall thickness was derived from the gaps between cells, whereas this grammar generates an abstract layout then makes it two-dimensional.

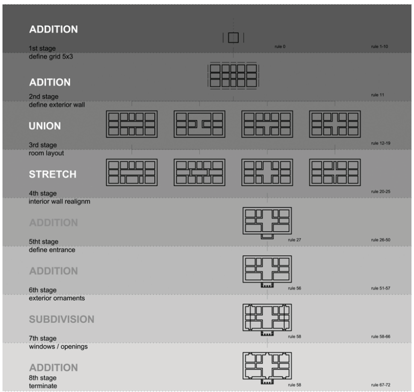

Figure 1. Original Palladian grammar derivation tree.

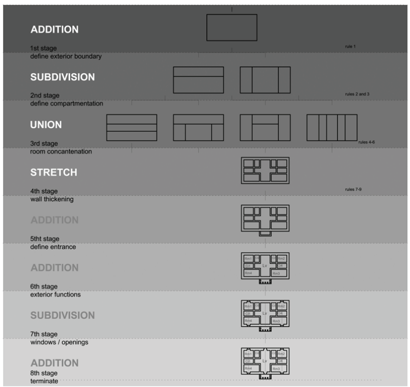

Figure 2. Proposed Palladian grammar derivation tree.

The fifth stage creates the entrance, consisting of a section extending from the core outwards to create an obtrusion. The definition of functional spaces, which had not been previously addressed, was fundamental and these were introduced in the sixth stage. Whereas the oblong spaces are mainly circulation areas, the rectangular and square spaces opposite the façades are the living areas, and the central space is the social area. The seventh stage involved the subtraction of volumes for openings. Windows are arranged in even numbers and the doors in uneven numbers. Internal doors are usually centred within the circulation area taking a centre line as axis. There are different window sizes for the different levels, the larger sizes being on the main floor, followed by the top level, whilst the smaller windows are on the lower ground floor. The design is completed with a label deletion (a technical stage), which is the eighth and final stage.

3. Shape rules

The rule system proposes three types of rules: addition, subdivision and adjustment. The first rule proposes the addition of a rectangular overall shape, with parameterisation based on the minimum and maximum acceptable areas, as illustrated (Figure 3). Subdivision rules include vertical and horizontal division, as exemplified in Rules Two and Three. These parametric rules represent the main operative process, allow for embedding (applied repetitively inwards or outwards) and can be used recursively (applied a number of times consecutively until the minimum usable space is attained). Subdivision rules respect the symmetrical design, hence the duplication of division in Rule Three.

Once the division has been executed, concatenation is used to arrange larger, complex spaces connecting adjacent rooms. To avoid unwanted space merging, these are applied only to borders, taking the adjacencies and symmetrical relations into consideration. The resulting space is displayed as an enclosed polygon. The west and east wings will be symmetrical. Deletion rules allow for the creation of complex spaces or a regular polygon boundary. Border deletion is achieved by using the forth fifth (horizontal and vertical) rules.

Wall thickness conforms to Palladio's specifications. The stone masonry construction used load bearing sheer walls as a tectonic method. The thickness of these walls is based on a generous safety coefficient that matches the construction grid lines and units. A depth of two Vicentine feet is prescribed for the walls (roughly 750 mm in metric system). The process is described in Rule Six, using an offsetting method. The desired wall centre will sit on top of the abstract layout.

Wall intersections are addressed in Rules 7 to 9, which propose the thickening of T, X, L combinations. Other addition rules add details, such as the entrance feature (porticos or loggias). These sets of rules are followed by other addition rules involving the inclusion of functions. The last set of rules provides for alterations using volume subtraction to include openings. They involve the positioning of windows, which are arranged symmetrically, or the positioning of doors. Uneven numbers of external doors are centred in the façade and internal doors are created to connect rooms.

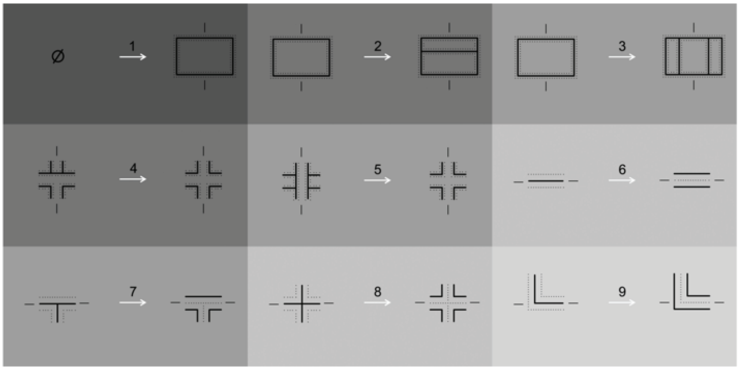

Figure 3. Proposed shape rules.

4. Villa derivation

Derivation describes the generation process in which the recursive application of shape rules leads to a final design. The original grammar showed how a successful design can be achieved, using the example of the derivation of the La Malcontenta villa (Figure 4). This was originally built between 1559–60 in Venice and is illustrated in Palladio's "Il quattolibbri" (Palladio 1997). In order to fully grasp the differences between the original and the alternative grammar, this was used for derivation. Despite the divergences (namely a more economical use of rules and process), both grammars contain the same number of stages. The new derivation process has 14 steps, using 10 shape rules sometimes recalled recursively (Steps 2, 5 and 6 using Rule Three, and Steps 3 and 4 using Rule Two).The first step is the boundary placement, followed by division in Steps 2 to 6. The division sequence of rules 3, 2, 2, 3, 3 splits a rectangle into three, or creates a variation of a 3×5 grid in which cells occupy a larger area for future occupancy. Step 7 deletes the vertical boundaries of the central cell. Step 9 offsets the preliminary layout by duplicating lines 2 feet away from each other and creating the wall placement. Step 10 deals with the intersections between wall lines and refines corners. Step 11 includes the entrance feature. Step 12 proposes functional uses by tagging each room. Step 13 creates openings in walls with the array or for window and doors. Step 14 terminates the design by erasing the labels.

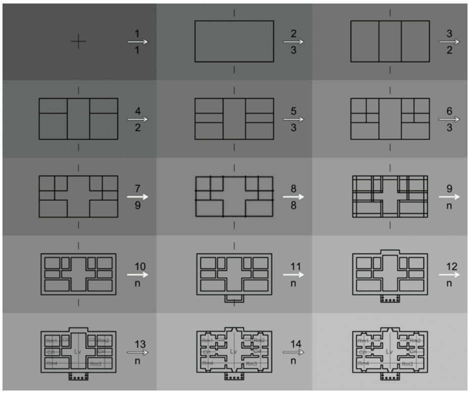

Figure 4. Derivation of the Malcontenta Villa.

5. Computer implementation

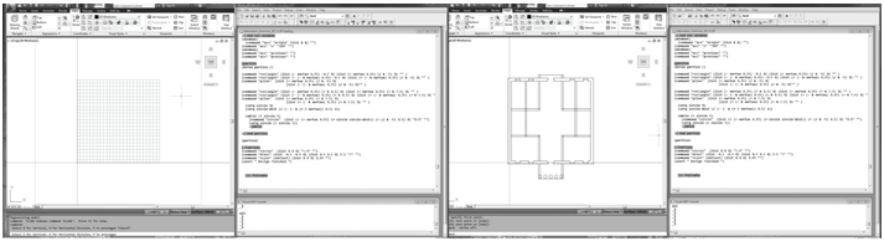

Figure 5. Computer implementation.

The computer implementation combines the shape rules, parametric formulation and conditions and actively assists in the complex application of the shape grammar. In addition, it reduces errors and secures the generation of solutions. Many languages were considered before AutoLISP, edited in VisualLisp, was selected as a dialect due to its object-based nature which facilitates implementation, using AutoCAD 2012 as a platform. The script was developed in a similar way to the grammar described in this paper (Figure 5). It focuses first on the plan view in 2D and then evolves to encompass the overall modelling of the villa, allowing for immediate visualisation of the design results in real time. The rules are implemented using different functions that can be called up recursively if desired and form and function are addressed sequentially. Stage 1 consists of the overall definition. The user is asked to choose the insertion point and area and the boundary is set using Palladio's proportion ratios, either a 1/1 square, a 1/2 rectangle or other appropriate ratios. The minimum and maximum areas are given as output and the user's input is optimised to the proportional ratios. Once the boundary is drawn, an indicative matrix is inserted using Palladio's Vicentine measurements (1 ft $\approx$0.354 m). The dimensions are rounded off to this system and the proportions conform to symmetrical classical principles.

Stage 2 allows the user to intervene in the design of the interior layout. Subdivision rules allow for horizontal and vertical divisions and the mouse input is registered on screen, with location justified to the nearest possible position in the Vicentine matrix. Both rules can be recalled a number of times, restricted only by the remaining free space and maximum grid size. Stage 3 involves spatial concatenation using a process of cell border deletion. The user can erase lines to generate a larger room and the input is recorded and repeated when necessary to maintain symmetrical layouts. Stage 4 transforms indicative lines into masonry wall dimensions. The exterior walls will be 2 Vincentine feet deep and the interior walls 1 foot deep. The offset process takes the centre line drawn and reproduces two parallel lines in separate layers.

Stage 5 reads the design accomplished so far and positions and sizes the entrance and rear porticos, emphasising the north/south symmetry axis with a similarly sized central bay. Stage 6 creates openings in walls for doors and windows. Windows are added symmetrically to the façades in an arrangement corresponding to Palladio's specification for even numbers. Every room should have an even number of windows. Exterior doors are arranged along the symmetry axis of each façade in uneven numbers. Stage 7 involves the assignment of functions, accessing the data input and addressing functions in terms of spatial situation (central or peripheral), connectivity (first level connection), adjacency and type (living, social or distribution areas). Highly integrated spaces such as the central area connect with other rooms to create social areas.

Rooms positioned in corners and represented as squares or rectangles with ratios of preferably 2/3, 3/4, 4/5, 3/5, 1/2 are living spaces (studies or living rooms). Rooms between other densely connected spaces (i.e. with two or more connections) that are smaller and oblong (with proportions of 1/2, 1/3, or 1/4) are distribution spaces (circulation areas, corridors, staircases and antechambers). This function labels each space and creates the adjacency diagram by connecting the adjacent circulation areas.

6. Conclusion and future work

This paper presents an alternative grammar for the Palladian villas, offering a fourfold contribution. Firstly, it demonstrates that two separate sets of design rules can generate the same corpus of designs. Secondly, it proposes a more economical grammar. Thirdly, it introduces functions to the grammar.

Fourthly, it involves the development of a computer tool which provides a user-friendly environment for exploring design.

Shape grammars are useful formulations that provide support for design generation. Their use allows for consistency in design through specific sets of formal and functional rules. As a rule system, it provides a framework for consistent design generation. Research so far has focused on shape grammars for encoding specific styles and generating new designs within a given style. However, to the best of our knowledge, generic grammars that encode several design styles have not previously been inferred. The development of such grammars enables tools to be designed that facilitate the generation of designs within the same typology, such as housing. This work is the first step in this direction. It is part of an attempt to encode existing housing grammars into a similar grammatical structure in order to discover higher-level patterns that can be encoded and then customised. If two distinct set of rules can generate the same set of solutions (recreating a specific language), then a higher-level grammar might allow for the creation of different languages. This generic grammar, once refined, could encode specific design languages. Two issues were addressed in this work, form and function, or, alternatively, space and occupation. These very important aspects of architectural design were encoded into spatial transformation rules, enabling the user to progress from generic shapes to detailed designs, facilitated by the use of a computer tool that incorporates design knowledge. This tool was scripted using AutoLISP. These findings have potential uses both in architectural practice and design theory. Shape grammars have proved to be powerful tools for exploring design whilst maintaining stylistic consistency. The proposed grammar provides an alternative method for designing Palladian villas. It is an attempt to generalise the use of grammars and ideally create a generic set of parametric rules that can be adapted to different contexts. Future work will address these issues from the perspective of inferring a generic shape grammar for housing.

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