

Rule Based Rapid Prototyping of Palladio's Villa Detail

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Abstract. This paper explores a method for the use of rapid prototyping devices to physically construct details of Palladio's unbuilt villas designs. The goal of the paper is to create clear identities of the rules used to physically build any villa. Results will provide rule instructions for the assembly of components for the physical construction of the 23 villa designs found in *The Four Books of Architecture*.

Keywords. Rapid Prototyping, Shape Grammars, Palladio

Figure 1. Students reviewing Palladio's original drawings in Vicenza. The drawings are of details Palladio observed while traveling in Rome.

Introduction

The Palladian Grammar identified a method of using rules to recreate a floor plan of the Villa Malcontenta (Stiny, Mitchell 1975). The shape grammar used to construct the plan drawing demonstrated how a number of plans could be generated in the style of Palladio through the application of shape rules. This paper is the first of three forth-coming papers focused on the use of rules for the physical reconstruction of 23 villas designs and the construction of new designs in the style of Palladio using rapid prototyping devices. This process calls for a means of rule representation and a new set of rules exclusively based on the villas' physical construction, not their pictorial representation. Here the focus is on the physical representation of Palladio's original rules from *The Four Books of Architecture* (Palladio 1965). This paper is a bottom up approach to design through the identification of detailed villa components, rules for these components and component parameters not listed in the *Four Books of Architecture* and the generation of new rules not listed in the text.



Rule Sets of Identities

Palladio's villa style is based on details applied to a structural system built of bricks. He offers two types of general rules in the corpus: design rules—those based on appearance, and construction rules—those based on the logic of villa construction. Here rules of the two types are identified in sets from which sub sets of identifiers and rules can be written. Each of the nine rule sets contains many sub identities of components and procedures for physical construction. A rule set such as "Walls," that identifies 5 sub rules based on wall thickness only needs construction

rules; there is no need for rules based on style. In contrast, rules for “Frames” are based on a geometric style of curves and shape proportions. The results will yield clear identities for a shape grammar composition that can be based on physical construction and visual style. These identities are taken from the first book of architecture and a survey of built villas. I have listed the nine rule sets :

- | | |
|--------------|---------------------------------|
| (1) Walls | - parametric formula |
| (2) Ceilings | - parametric formula |
| (3) Stairs | - parametric formula |
| (4) Columns | - parametric object |
| (5) Doors | - parametric formula |
| (6) Windows | - parametric formula |
| (7) Frames | - parametric object |
| (8) Roof | - parametric formula |
| (9) Details. | - parametric object and formula |

Each rule starts with an identifier, and here are two methods for creating identities for villa components or a procedure. The first is defined as parametric objects—these are components of a determined shape (columns and frames) that will ultimately be scaled to fit an opening. The second and most common type of rule set are those built by numerical procedures. For example Palladio offers numerical formulas for the size and proportions of door openings while columns and door frames are predetermined parametric shapes that can be altered to fit a particular opening.

Printing Identifiers in Three Dimensions

Rapid prototyping is a means of mechanical production from a CAD file of any shape without the expectation of identical reproduction. Each object produced by a rapid prototyping device can differ in its outcome from the previous representation. The goal of rapid prototyping is not to

present one instance of a design rule, rather it is used to produce physical representations of variations from an initial identity, thus offering a choice of details that can be applied to a floor plan drawing.

Technically, digital fabrication of any type requires more information than drawings. Here the sizes of villas parts were taken first from Palladio’s text, second from field observations of the Villas Cornaro and Pojana Maggiorie and third, a few assumptions from photos. There are many villa components whose dimensions are not easily identifiable from photos and drawings, such as the depth of the ceiling to the floor above in a segment vault or the rail thickness for a balcony constructed of stone balustrades. In these cases proportions were assumed based on photos and drawings. There are nine sets of details and over 50 detail subsets from the nine. Again these are the 50 initial shapes or constructs; new rules will be generated from these.

Rules and Information

After the identification of the 50 rules was completed and a CAD representation of each rule was built, a series of physical representations was printed of each identity using a three dimensional printer. Each rule identifier will represent the initial shape in what will ultimately become a shape grammar. Most grammars built of rules are created by shapes and are missing information needed to determine the logic of the application, in particular at the detail level. By creating identifiers that are close representations of Palladio’s detail style and an explanation of the construction logic, there is a basis from which new variations of the style can be created while upholding its structural integrity. Later the detail will be compared on a part by part basis for a verification of the style [Stiny, Mitchell, 1978].

Each 3D print is intended to stand as a clear example of a book print raised off the page in three dimensions. The process represents layer

by a layer method of printing in three dimensions. This is the opposite of a wood cut used by Palladio to replicate images in *The Four Books of Architecture* by removing material from a solid object. The components in each print are of a different scale, because the goal was to express the three dimensional character of the rule and not the ultimate set of shapes. Each print measures 8" wide x 10" high x 2" depth. They represent the initial set of rules from which many detailed assemblies can be constructed.

This method contrasts with methods used to write Palladio's text during the age of mechanical reproduction (Carpo 2001). Palladio used the woodcut to reproduce images alongside his text almost a century after the woodcut was invented. This method of reproduction made Palladio's work accessible to architects such as Indigo Jones and Thomas Jefferson. Eventually access to these models will be in the form of on-line CAD files.

Figure 2. Initial identifier of an Ionic column in the form of a plaster three dimensional print.



Conclusion

To reconstruct a Palladian villa, two sets of rules are necessary. The first set is design rules, a top down set of rules used to organize space and forms such as moldings. The rules are created from information on the site, client needs and

function. Design rules are primarily used here to produce a floor plan diagram. The second set consist of the nine rule sets listed above, which are based on the logic of how the components are constructed and are applied to the floor plan diagram. The outcome of these two sets of rules yields information for the physical construction of any villa's design in three dimensions. The Palladian Grammar declares that the rules of Palladio's style are embedded in the shapes used to compose a design. This paper claims that a large portion of the rules used to define style are based on the logic of construction in addition to stylistic shape rules. This order of structure and style are seen at the local level of a villa component as well as the overall design. Columns, regardless of type, contain a structural component and a stylistic component. The structural information is based on the logic of construction while the details are based on shape and proportion.

The research has shown that the intention of this bottom up approach learning rules is not to create a deterministic representation of details applied in combinatorial way to any floor plan. The intention is to create components that will serve as initial shapes from which rules can be written based on the logic of brick construction and some elements of style. Palladian villas are composed of an assembly of many components within in a finite set of rules and an infinite set of sub rules. These sub rules emerge from the original rules during construction. In the built villas this emergence could have come from a particular mason's interest in building. Palladio may have offered a basic template for the mason to follow from which a new detail emerges once the mason applies his own details to Palladio's example. The new detail can be based on the mason's methods, background and relationship with Palladio. Palladio used a few drawings to describe a building to a mason, which meant that Palladio was

open to a mason's interpretation at certain detailed areas. In this study, the understanding of emergence will come from assembly of components to create detailed areas of the villas, and from testing the rules through rapid prototyping.

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VHDL-based rapid system prototyping. The Rapid Prototyping of Application-Specific Signal Processors (RASSP) [1] program of the US Department of Defense (ARPA and Tri-Services) targets a 4X improvement in the design, prototyping, manufacturing, and support processes more.Â stages of design refinement, ending with a detailed hardware design. This hardware/software codesign process is based on the RASSP program design methodology called virtual prototyping, wherein VHDL models are used throughout the design process to capture the necessary information to describe the design as it develops through successive refinement and review.