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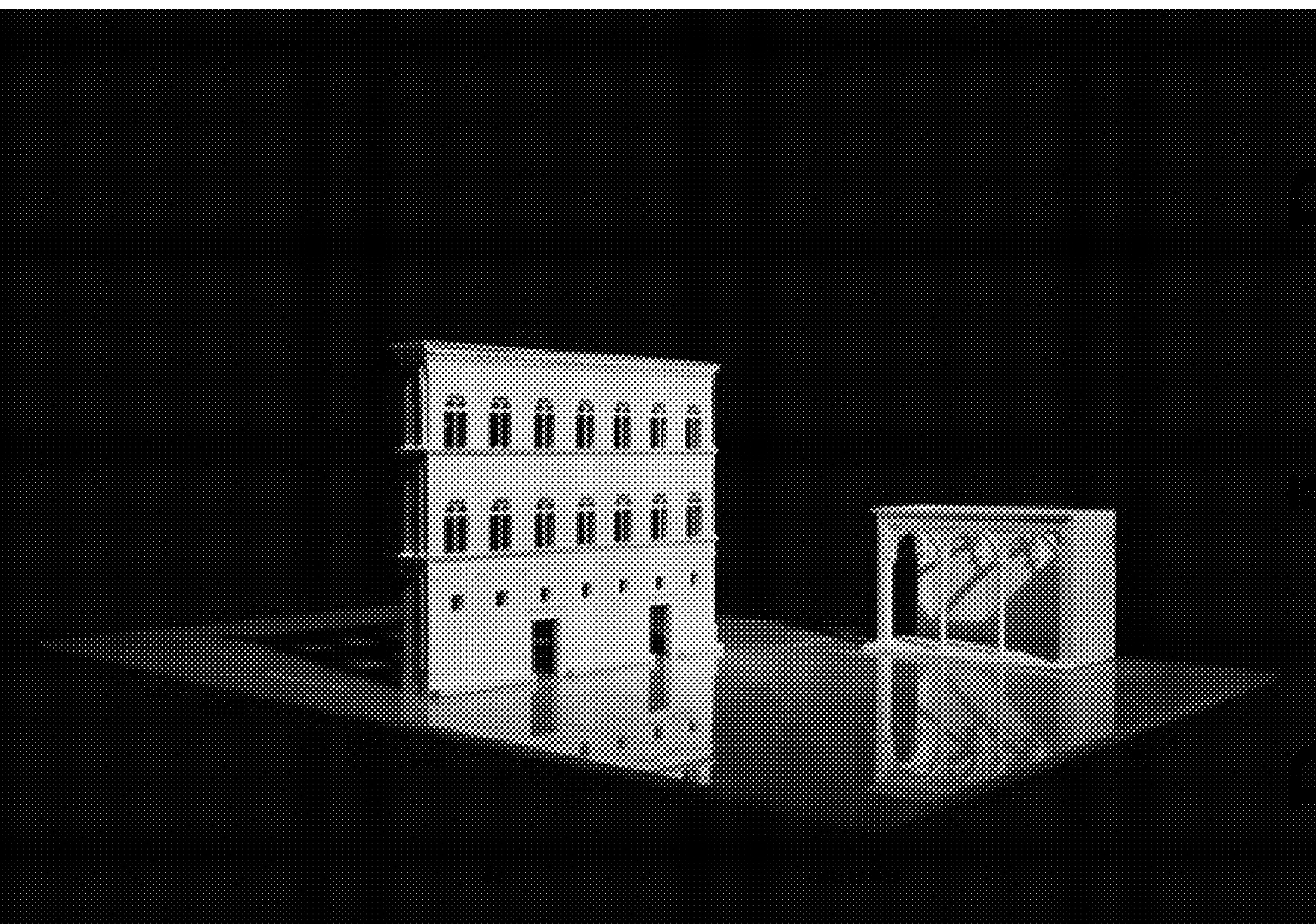
De re aedificatoria Column Systematization Shape Grammar



0. Digital Alberti exhibition, Coimbra, 2013
Do mal o menos

1. INTRODUCTION

An underlying influence of Alberti's theory is felt in classical architecture in Portugal, but no one was able to determine the extent of such an influence. The idea is to contribute for further methodology and data by translating the treatise into a description grammar (Stiny, 1981) and a shape grammar (Stiny and Gips, 1972) and tracing the influence of Alberti's work by determining to which extent this grammar can account for the generation of some Portuguese classical buildings. This approach follows the transformations in design framework proposed by Knight, (1983) according to which the transformation of one style into another can be explained by changes of the grammar underlying the first style into the grammar of the second. The income paper will show the developed grammar that leads us to some implementation as computer programs (Python and Grasshopper). The output digital models (2D and 3D) will be used to produce drawings and rapid prototyping models.

2. METHODOLOGY

Alberti's treatise can be thought as a set of algorithms that explain how to design buildings according to the canons of classical architecture. The aim of this research is to translate the algorithms in the treatise into a description grammar, then into a shape grammar, and finally into a computer program (Li, 2002). The "understanding of the treatise" aims at gaining a deep understanding of the treatise by manually designing buildings according to its rules and then producing the corresponding 3d models using rapid prototyping; "inferring the grammar," aims at developing the grammar thereby gaining insight into the formal structure of Alberti's interpretation of classical architecture; "implementing the grammar," aims at writing the computer program encoding the grammar; "matching the treatise grammar," aims at matching the grammar with actual buildings designed by Alberti and some others from Portuguese territory.

3. BUILDING THE SHAPE GRAMMARS

Structure

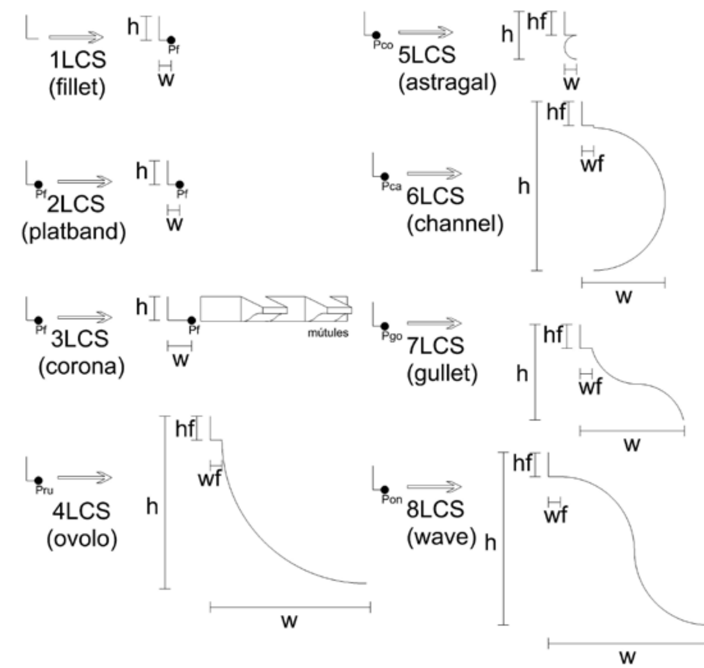
Reading and extracting the parameters from *De re aedificatória,* which is a text without illustrations, lead us to a flowchart representing the structure of the elements in order of appearance in the text. It was used to understand the algorithmic nature and function of Alberti's descriptions. It was then possible to establish some shape grammar composition rules. A first attempt of interpretation using symbolic descriptions with a brief *Autolisp* and *Grasshopper* program was used to test how to generate parts of columns true Alberti`s description of Moulds using, recursively, compositions of the letters L, C and S (named: platband, corona, ovolo, astragal, channel, gullet and wave). See image 1

A grammar of the elements of intercolumn (2 columns and an entablature) with 2 views and the columnsystem grammar compreending 4 views (a parallel grammar): plan, façade, section and an axonometric. The algebras (U= Form algebras; V= Label algebras; W= Weight algebras) were used in different 1, 2 and 3 dimensions, and 0 (empty set) for initial rule.—*sc*: column system and *ic*: intercolumn—are associate views giving them more characteristics and elements incorporating more versatility.

esc: <U12 V12 U13 U33 V13>
ie: <U12 V12>

A shape grammar is a set of rules of transformation applied recursively to an initial form, generating new forms. The column system grammar initial rule is a point that generates both the area to built (site plan) as well as the column and the portico (structure and ornament). As said before a diagram was used representing the algorithmic construction of each element of the system of a column as the Base, the Column, the Capital and the Entablature. Alberti distinguishes each part of the elements by giving parameters and then subdividing them (the moulds). This innovative description by letters show an Aristotelic way of description, relating the parts and the whole. (Frommel, 2007)

The column system grammar was appointed in this way: first the initial rule where everything starts, then a generation of a line with potential insertion points, then a "proto" portico made of primitive solids (cylinder, prism, etc). Then, rules to generate each part of each element (with more complex solids as torus, half torus and others made possible trough Boolean operations) and so on. Then all the grammars of the different column system elements, as variations of the doric base <db>, ionic base<ib>, shaft (plain, with 20 and 24 channels) <sh>, doric capital<dc>, ionic capital<ic>, corinthian <cc>and composite capital<ccm>. Doric<dent>, ionic<ient> and corinthian entablature<cent>. From this set of grammars other grammars were produced to generate main nave longitudinal facades (presented in this paper) and facades from palaces showed in further articles.



1. LCS system rules

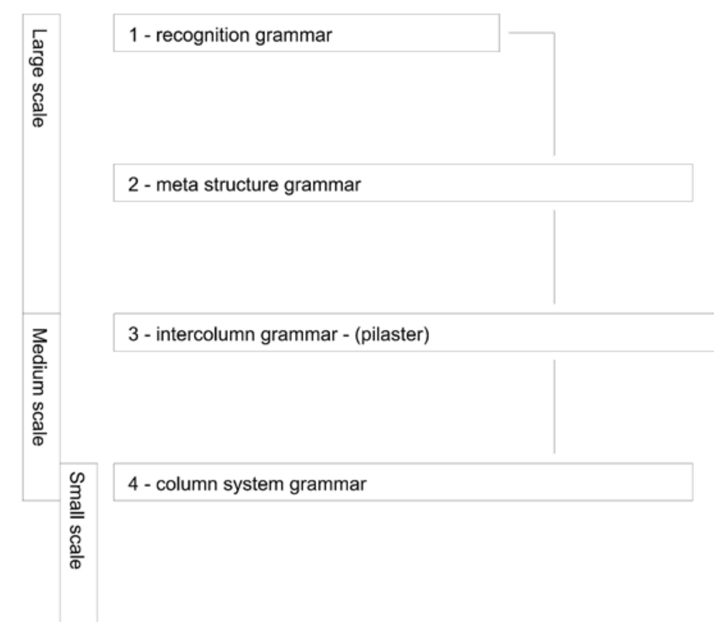


Diagram 1 — Stages of derivation

4. SÃO VICENTE DE FORA CHURCH CENTRAL NAVE FAÇADE SHAPE GRAMMAR

Established in 1147 by King Afonso Henriques both the monastery and its church of São Vicente de Fora had their reformation by King Filipe I in the 16th century. It is believed that these renovations followed drawings of Juan de Herrera who was in Lisboa by 1580-1583 and the drawings of Filipe Terzi (Soromenho, 1995). The Portuguese architect Baltazar Álvares was in charge of directing the construction from 1597 to 1624.

São Vicente de Fora Point Cloud Model (PCM)

In order to have feasible elements from *São Vicente de Fora* a terrestrial laser scanning (TLS) surveying was made using a phase-based laser scanner (FARO Focus 3D) producing 24 colored point clouds.
The registration and decimation of the PCM were done with the open source software MeshLAB. The PCM final alignment was done using their matrix and was the basis for the extraction of ortho images, multiple sections and triangulated models. Several 2D drawings were produced using JRC software. The final project .Aln containing the alignment of the 24 PCM was sectioned in vertical and horizontal planes. After using the 2D drawings from the TLS in the construction of the grammar, it was evaluated and compared with Alberti's rules. (Coutinho, 2013a)

Rules and derivations stages

The derivation of shape grammar rules is a process of applying a rule to a shape or sub shape recognized in a wider shape. A specific rule may be applied once or recursively. The derivation process is a critical moment of shape grammar rules application and may provide the feasible generation of a desired design in a previous defined style.
In the diagram 1 is showed the different stages of derivation.

They were divided in large, medium and small scale. The grammars may be derivate in 4 stages:

Stage 1 — Where a set of rules recognise some shapes given from parts of a plan and a section of a church — a central nave longitudinal façade — generating floor and wall axis to be use in next stages.
It comprehends 5 distinct rules as seen at image 2.

Stage 2 — A set of rules insert axes and labels of pilasters and column elements. These rules (see image 3) are parametric.
They behave according to certain measurements relations.
A set of parameters and conditions are used to manipulate labels.
This parameters have +3/2wch; K1 = 4 in rule 1vp, and L1 = k2D+2wIch+3/2wch; k2 = 5 for rule 2vp. Both rules have the sum.

$$\left(\sum_{k=1}^{k1+k2} D\right)+6wIch+9/2wch;\ \forall\ \{wIich,\ wch,\ D\} \in R \wedge k \in N$$

Stage 3 — Dedicated to the redefine the pilaster, uses a set of rules (image 4) from the intercolumn shape grammar. A description from the book VI chapter 12 pp. 402 produces a transformation rule such as <bd> ®S <bd> transforming a doric base with its plan inscribed in a circle used to sweep the vertical section (profile) in an extrusion, in to another base inscribed in a rectangle extruding its vertical section (profile) along it as seen in image 5.

Finally stage 4 — inserts the column systems elements in the label generated in stage 2. Rule e erases all labels. The complete derivation is showed at image 6 and an axonometric rendering out of it is showed at image 7

Transformations

As said before one role of the grammar is the generation of the design of the central nave longitudinal façade of the *São Vicente de Fora* church. With such generation we aim to verify if its elements can be obtained from Alberti's rules or some sort of transformation of such rules. There are at least four different ways of transforming a grammar namely, rule addition, rule subtraction and rule changing, which can be designated by letters *A*, *S*, and *C*, respectively. (Knight 1994)
A fourth transformation type *I* can be added if we consider that a rule can remain unchanged, This transformation I is important for our study because each time such a transformation is used, it may suggest that there is strong evidence that the designer was knowledgeable of Alberti`s rules. (Coutinho, 2013 a).

In this grammar the transformations were:

In stage 2 the transformations are parametric changing the sum of the expressions. The intercolumn proportion verified was 5D+3/4D width (W) and 10D+1/2D height (H), closer to albertian proportion of 2:1

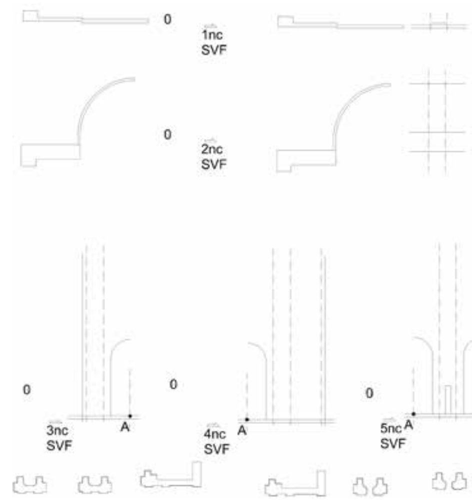
The stage 3 is about the proportions of the pilaster. In this case de thickness is close to 1/4D being in the range of the thickness proposed by rule *2c ad* showed in image 4.

In the stage 4, dedicated to column system elements application, a doric base, a plain shaft, a corinthian capital and a doric entablature are in use having proportions closer to *De re aedificatoria*.
The variations verified are:

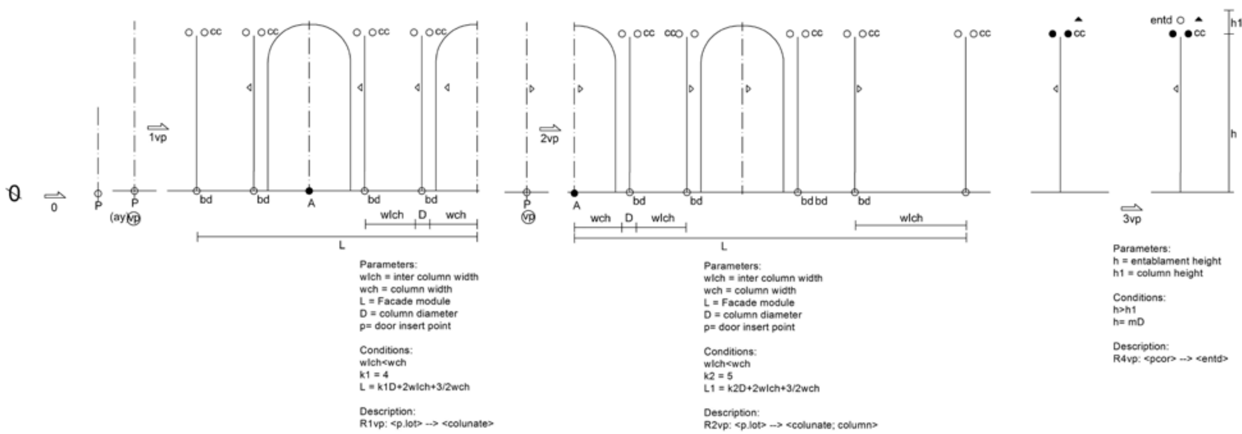
Base — superior torus 1/10H > H (albertian superior torus); added 2 fillets with 1/2H (albertian fillet); inferior torus 1/8H > H (albertian inferior torus). Shaft — inferior fillet 2H (albertian fillet); collar H < 1/3H (albertian fillet); Entablature — in the architrave there is a slight variation smaller than 5% (Krüger 2013) and considered in the range of the treatise;

The frieze is coincident as well; in the cornice there is the gullet before the pavement has its radius > 5r than the one frome the treatise. Finally the pavement has a length of 20 parts and the Alberti one is 12 parts.

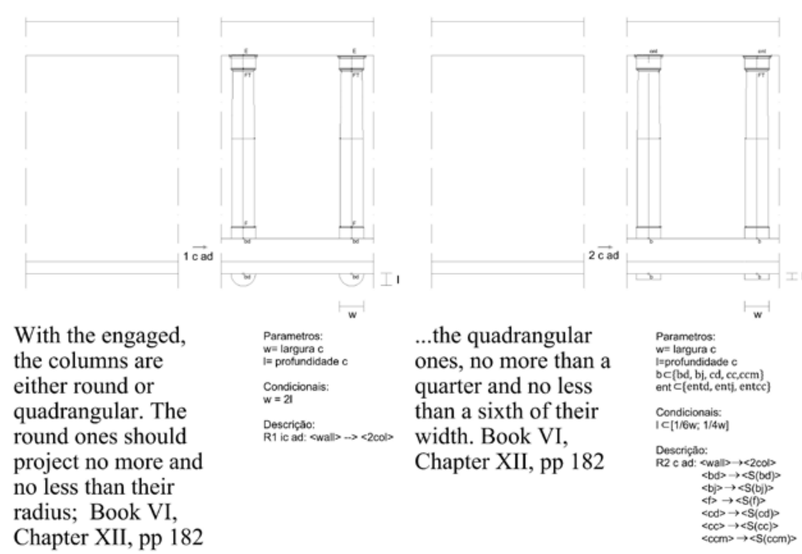
2. Set of recognising rules from stage 1



3. Set of rules to generate a meta structure from stage 2

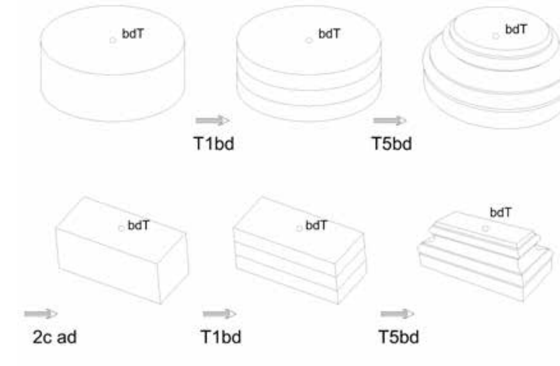


4. Set of rules (of addorsed columns) from the intercolumn grammar to be applied at stage 4 producing pilaster elements.

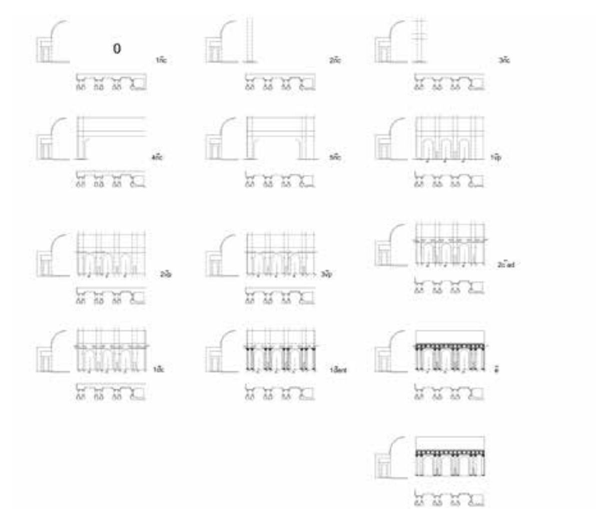


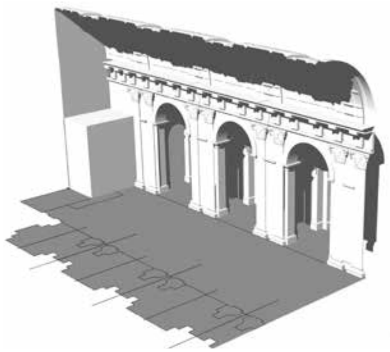
PAPERS

5. Use of rule 2c ad to transform a doric base.



6. Derivation of the central nave longitudinal façade of the church São Vicente de Fora in Lisboa





7. Rendering of central nave longitudinal façade of the church São Vicente de Fora in Lisboa.

5. DIGITAL FABRICATION OF ARTEFACTS PRODUCED WITH THE GRAMMARS.

Several technics and different tools were used to fabricate artefacts. It was used rapid prototyping tools as 3D printers and CNC Pronum 3 axis milling machine to fabricate part of capitals components. The goal of such use was: to fabricate elements to understand their morphologic nature, as volutes, leafs and the connections between different elements, etc. This experiences were used as a strategy of design enhance of the rules having a direct impact on the construction of the shape grammar; (Coutinho, 2013b) evaluating the final elements out of the rules derivations, comparing the artefacts with the real ones; as a way of showing and communicating the different aspect of the buildings, exposing parts of column elements, parts of facades and interiors. (image 8)

6. CONCLUSIONS

The methodology and incoming results shows that grammars can foster a better understanding of complex matters and is suitable to transform algorithmic descriptions—in this case given by a text and buildings—in a tool that allow designers and historians to improve their performances and be more precise generating designs, analysing and produce them. The transformations observed in the central nave longitudinal façade of the *São Vicente de Fora* church shape grammar were in the final stages of derivation and the column elements out of the column system shape grammar were parametrically changed. There were no topologic variations. That means that the natures of the rule changes were almost coincident from the treatise ones.

8. Column elements and buildings prototypes fabricated with different rapid prototype technics.

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