A SHAPE GRAMMAR TO GENERATE LOGGIA RUCCELLAI

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Abstract. This article shows the result of generating a 3d model of Loggia Rucellai in Florence using a shape grammar from Leon Batista Alberti’s treatise De Re Aedificatoria and it is a test bed for further generations of buildings using Alberti’s rules. It shows the accuracy of such grammar to help tracing the degree of influence of Alberti’s treatise in Renaissance Portuguese architecture. Rucellai palace facade ornaments and its interior loggia where used to analyze and compare the Loggia generation accuracy. A Grasshopper script is used for the automation of the rules derivation. An evaluation process is presented and its use aims to better understand the deviations between the treatise and the Loggia grammars.

Keywords. Alberti; shape grammars; transformations in design; grammar evaluation; digital fabrication.

1. Introduction

The research presented in this paper is part of a larger project aimed at understanding the cultural impact of Alberti’s treatise on classical architecture, using a computational approach called Digital Alberti based in Coimbra University, Portugal. Namely, the project aims to determine the influence of Alberti’s treatise on Portuguese architecture in the Counter-reform period.

Based on document sources that reveal links between Portuguese architects and Alberti’s work, some historians have pointed that such an influence was real, but
none was able to determine its extent so far. The idea is to shed some light on this discussion by translating the treatise into a shape grammar (Stiny and Gips, 1972) and then trace the influence of Alberti’s work by determining to which extent the grammar can account for the generation of Portuguese classical buildings (Kruger, 2011). This approach follows the transformations in the design framework proposed by Knight (1983) according to which the alteration of one style into another can be explained by changes of the grammar underlying the first style into the grammar of the second. The project foresees the development of grammars as showed in this article, encoding the rules for designing the column system and rules for designing buildings, namely churches and in this case a Loggia.

The decision to generate the Loggia as a target element to be analyzed was due to its physical proximity to Rucellai palace as seen in Figure 1. The loggia construction is contemporary to the construction of the palace. This double condition associated to a wider consensus on Alberti’s Rucellai palace authorship set up a good test ground for the analysis and verification of the ornament, as well as the proportions used initially in the existing buildings and then in the loggia generated. It is possible that both constructions were built by the same workers, suggesting that some information was conjointed between the palace to the Loggia builders. Supporting the idea that there is a coherent relationship within the Loggia and palace ornament elements and proportions employed. In that way it might be possible to verify a pattern of design procedure by the Loggia architect.

This article will present the grammar for the Loggia Rucellai, using a grammar of the treatise centered in the Doric, Ionic and Corinthian orders as well as the
columnate grammar sections. A sketch will demonstrate the computer implement-
tation of such a grammar.

Since the Renaissance, the authorship of architectural design has been one of
the issues under discussion among different specialists in theory and architectural
history. Redefining the condition of the architect as one who operates the complex
world of meaning of the elements of architecture and its “concinnitas” Alberti had
repositioned the architect’s activity among those liberals ones, separating him
from the operative and craftsman association since medieval age. This autographic
condition of the architect as Carpo (2011) has pointed out, is highlighted with con-
struction of Renaissance buildings such as the Florence Cathedral dome, whose
authorship was claimed by Brunelleschi. The indeterminacy of the authorship of
the buildings assigned is related to the social, artistic and professional emancipa-
tion of the architect.

Alberti, like many other architects/thinkers operated jointly with a nucleus or
guild of builders. Some of those who collaborated with him, and were directors of
construction in the field are Mateo de’Pasti in Rimini, Bernardo Russelino in
Florence and Luca Fancelli in Mantua. There are contradictory opinions regarding
the authorship of Rucellai palace, many attributed to Rucellino following Alberti’s
concept and design with reference to his Piccolomini Palace in Pienza. We will
attempt to contribute to the definition of Loggia Rucellai author/architect use of
Alberti’s rules present in the treatise, but not provide proof it’s authorship.

The Loggia Rucellai is full of social meaning, as Kent (1972) said “the family
loggia in the Piazza Rucellai, the first urban space of the Renaissance created for
the special benefit of a powerful patron”. It also provides spatial and architectural
significance because it consists almost exclusively of elements of the column sys-
tem. It is the column systematization per se. The construction of Rucellai palace
started in 1448. The loggia of the palace (note that this loggia is inside the palace
and served as comparative model) and its inner courtyard were concluded in 1455,
as the facade of the palace began in 1461, there is strong historical evidence of
Alberti’s participation on the facade design. The Loggia Rucellai was completed
in 1466 ready for the marriage of the daughter of Cosimo Medici, Nannina and the

2. The Loggia Shape Grammar

Generically this grammar is an analytic grammar and comprehends a shape gram-
mar, a description grammar as well as a program of the target element or building
to be generated.

The derivation process of the column systematization has different stages. The
first stage regards an insertion of labels in a line (that may come from the site
plot); the second stage: an insertion of column base; the third stage: an insertion of shaft; the fourth stage: an insertion of a capital; the fifth stage: an insertion of latastrum (only when a corinthian or composite capital is in use) and arch or architrave; the sixth stage: an insertion of an entablature; and finally, the seventh stage: to insert the intercolumn. When the target element has a façade, windows and doors are the last elements to be inserted (Building stage).

Then each of the above stages has sub-stages such as: in the first stage the line may be divided in multiple points marked with labels; in the second stage the column base may be Doric or Ionic and each of those is divided in different elements (e.g. plinth, torus, fillets and scotia); in the third stage the shaft may be plain or with flutes; in the fourth stage the capitals accepted are Doric (with 2 variations) or Tuscan, Ionic, Corinthian and Composite; in the fifth stage the arches and architraves may have Doric or Ionic ornaments; and in the sixth stage the entablature may be Doric, Ionic or Corinthian. In the seventh stage the intercolumn may have an engaged or detached wall, or be empty. Finally the façade may have Doric, Ionic or Corinthian doors (2 variations: pediment and engaged or detached lateral columns), window and pedestal.

The grammars were developed as parallel grammars encompassing four views: plan, section, elevation, and axonometric (as shown in this paper due to space constraints). The function of the derivation stages is to better control the different grammars in use and ultimately to mark where the transformations occur. The first three of these views are developed in the Cartesian product of the algebras $U_{12}$ and $V_{12}$, and the fourth in the Cartesian product of the algebras $U_{13}, U_{33}$ and $V_{13}$ such as the grammar presented in this paper. Each rule has a section containing both parameters, descriptions and, when needed, a set of functions to be coordinated with other grammars. In this article we show the rules that allow generating a colonnade and the Loggia Rucellai. It is given a place of insertion of columns and horizontal elements (arches and entablature) proceeding to the application of the various rules recursively to generate the Loggia using elements of ornament described by Alberti.

The rules consist of drawing elements and a set of descriptions. The drawings of this grammar are represented in perspective and they contain, besides the elements of the column, an axis of symmetry of the element and a label at the end of this axis comprising two parallelepiped L shapes with green colour. The function of this label is the spatial orientation and localization of the 3D model facilitating the understanding of the rule and the subsequent rule to be applied. Each rule has a set of descriptions. They are composed by defining the conditions encountered in the drawing, the parameters used for these conditions and ultimately a function that provides a framework and identify the provenance of the rule in use. This function is associated with an inference table that will manage the use of these functions relating them with the different derivation stages, providing a greater control allow-
ing the generation of grammars. One of the purposes is to control the parallel use of grammars, understanding if certain rules are being repeated or even if they do not belong to the corpus. If a rule is not employed but necessary for the generation of the element, we can then conclude which rules or set of rules or even new grammars have to be added, subtracted or transformed and in what stage are they related.

3. Implementing the Grammar and Derivation

The rule 0 assigns a line from the site plot at Via del Purgatorio in Florence (Figure 1) and divides it in 5 different segments. The bigger ones are given to generate the inter column and the rest are guide lines to generate the pilaster. The mathematical expression is such as \( 3D + 2wPilaster + 3IC = L \) where \( L \) is the length of the site plot and \( wPilaster \) is the width of Pilaster and \( D \) is the column diameter. IC is the inter columnio.

Rule 1 assigns a point \( P \) from the site plot line. In this point a generic column, a cylinder, is going to be positioned. Rules 2 until 7 are related with previous grammars, they are evoked from previous grammars and are assigned and articulated with a function to manage its use, not allowing it, in this case, to be repeated. This function is such as \( <Db><s><Cc> \) (rule 2) meaning \( <Db> \) a state (usually related with the final sub stage) of the generation of the Doric base grammar. \( <s> \) is the grammar of the shaft and \( <Cc> \) for the Corinthian capital. The reason for such machinery is that, according to Alberti, the user is “invited” to use various elements in any kind of order subverting the Vitruvius’ logic of order type use. Rule 8 is a new rule. It is a transformation of a pilaster, being taller and in fact a union of two similar pilasters resulting in the outstanding external double corner. This pilaster is added on the corner and is related with the rule 9. Rule 9 is another new rule adding a platform with 2 steps where the entire Loggia will fit. Finally, an M rule is created; it is a rule that makes the mirror at the final steps of the generation. And an E rule erases all the labels and notations, finishing the derivation. See the rules in Figure 2 and derivation in Figure 3.

The computer implementation of the rules of the grammar was done using a Grasshopper (GH) code regarding an automation of generation. Other experiments aiming a full implementation of grammar are being carried out using Python scripting in particular and CGA applied to City Engine. However these results will be presented in further publications.

4. Evaluating the Generation

As said in section 2, this grammar has a shape grammar, a description grammar and a program to be assigned in the generation of a specific target building, in this case the Loggia Rucellai.
The program uses mostly the list of ornament elements from the real building to be generated. The Table 1 serves to fix systematically the system elements of the column in the building in question. Then each element is checked with the ones existing in the treatise grammar. Through the overlapping of data we can get an accurate idea of elements that are added, subtracted and transformed. By analyzing them in more detail the aim is to understand, quantify and qualify the nature of those changes. A GH code was used to detect the elements not specified by the grammar as seen in Figure 5.

The comparison and evaluation process employed to generate the grammar held up by applying grammars from the treatise. One virtual artifact (3D model) was produced and subsequently prototyped gaining knowledge from this process towards the theory validation, the evidence of Alberti’s treatise prescriptions use in Portuguese architecture, as Figure 4 shows.

The artifacts (3D model and a rapid prototype) obtained were compared with the real building through photographs in different perspectives as well as different details of the system elements of the column as seen in Figure 6.
Table 1. Existing elements at Loggia Rucellai Building.

<table>
<thead>
<tr>
<th>Loggia Rucellai</th>
<th>Main facade</th>
<th>Lateral facade 3st floor</th>
<th>Interior Loggia</th>
</tr>
</thead>
<tbody>
<tr>
<td>2stepsplatform/db/sh/corintean-Ca/abacus/arch with dEnt/</td>
<td>2stepsplatform/db/sh pilaster/corinthian-Ca/abacus/arch with dEnt/dfrieze with inscriptions</td>
<td>Fan vault ceilings</td>
<td></td>
</tr>
<tr>
<td>Corner pilaster with Base db/sh pilaster/corintean-Ca/</td>
<td>Corner pilaster with Base db/sh pilaster/corintean-Ca/</td>
<td>springs</td>
<td></td>
</tr>
</tbody>
</table>

Legend: db-Doric base; Sh-shaft; Sh pilaster-shaft on pilaster; Ca-capital; dEnt-Doric entablature.

Figure 4. Flow diagram.

Figure 5. Comparing lists of elements to detect the ones to be added.
There was no ruled survey used for comparison in this phase of the research and it is to be said that it may contain some degree of imprecision. Meanwhile we believe that the degree of inaccuracy does not prejudge the conclusions made because they are based on an analysis of the proportions of the column system elements (dB, Sh, Ca, dEnt, etc.). If the proportions would show large deviations among the elements, this work could not be done with this methodology and surveys would have to be carried out in the field. With this methodology (applied for this specific case) we gain some economic costs avoiding long distance travels.

4.1. RAPID PROTOTYPING

Aiming the accuracy verification of the generation, the digital model generated was printed on a 3D printer of Zcorp, a model of part of Loggia as seen in Figure 7.

This prototype helped us detect some mistakes on the positioning of the arches of the roof and how they unload in “latastrum” of the corinthian capital. There

Figure 6. Comparing real Loggia Rucellai with its 3D model.

Figure 7. Partial rapid prototype and GH code for 3D model of Loggia Rucellai.
5. Conclusions

The process showed in this paper is also a process of counting parts and reasoning on those parts as seen. But it also presents a method to control that information towards a deeper understanding of those parts counted.

In the derivation process there were 3 new rules added to the former grammar. Rule 8 was generated from the initial line (Rule 1) described as $3D+2w_{\text{Pilaster}}+3IC = L$. The corner Pilaster has a width such as $w_{\text{Pilaster}} = 6/5D$ (column diameter). Its height is $h_{\text{Pilaster}} = 10+1/2w_{\text{Pilaster}}$ suggesting an Albertian height of corinthian column was used. Looking even closer, it’s possible to verify that the Pilaster has a Doric base with $1/2w_{\text{Pilaster}}$ and a Capital with $1w_{\text{Pilaster}}$ being coincident to Alberti’s prescriptions. The columns of the Loggia have a height (containing a latastrum) of $h = 7D$ and the Corinthian order at Rucellai palace has $h = 7+1/4D$. Alberti’s are $9D$. The base is close to $3/4D$ (which is in the parametric variation of $1/2D \leq dB \leq 3/4D$ from the treatise). The total height of the column (the space from the floor until the arch or entablature) is accomplished by the shaft parametric variation. This transformation was occurred in stage 3 of the derivation. This may suggest that, in terms of construction, the column elements were built in the workshop and the shaft may have been the last to be cut.

The transformations found and the application of some formal elements is almost the same in the Loggia as in the palace. The corinthian capitals leafs used in the Loggia are formally similar to the ones used both in the interior palace loggia and courtyard and in the first phase of the Rucellai palace facade construction.

The rule 8 and 9 are new rules. If rule 8 is a parametric variation of the rules to generate a column shaft present at stage 3, rule 9 is not contained at the 7 main stages. Rule 9 regards the generation of the floor and wall within the derivation boundary. This rule generates 2 steps at Loggia Rucellai derivation. Due to renovation works at the palace loggia it’s not possible to conclude if there is any similarity among them in this particular aspect.

It is concluded that there is an application (intentional or not) almost directly of the rules described in the treatise by the author and builder of the Loggia Rucellai and that some of the solutions for both buildings (palace and Loggia) are similar. If future applications of grammars are to generate the buildings from a target sample of historic relevance (with high probability of Alberti’s influence), we may conclude that who created it had knowledge of Alberti’s rules (particularly by those who traditionally are considered architects in field working close with Alberti: Matteo di’Pasti, Bernardo Rosselino and Luca Fancelli) and even some of
the builders of works in which Alberti did not participate as a designer. It might be possible to verify a pattern of design procedure. Finally, the results show that a derivation of rules may generate a 3D model very close to the real building suggesting that it is possible to generate architectural space with elements of the system of the column, i.e. the systematization of the column.

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