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Parametric Representation of the Architectural Orders: Testing of Parametric Modelling for Simulation and Interpretation of Classical Architecture

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Abstract

The Architectural Orders have always occupied a key role in architectural doctrine. During the Renaissance, after the rediscovery of the Vitruvian text, each of the most famous architects gave their own interpretation of composition and proportion with respect to the Orders. After a careful analysis of some of the main treaties, it has been necessary to determine a unified interpretation of the genesis of the Orders and to create a single digital model that could be declinable in various versions. By advanced digital techniques, it was possible to generate a representative algorithm in a basic modifiable structure using different parameters. Results are also important due to the direct comparison between authors. The algorithms may also support accurate representations and interpretation of the actual artefact's shape, allowing us to hypothesize the author's style and, in case of restoration, to operate in a consistent way.

Keywords: Architectural Orders, heritage, modelling, Renaissance, restoration

Introduction

In architectural history, after the remarkable position in classical times and the subsequent oblivion of the Middle Ages, Renaissance architects rediscovered classical orders and their proportions. The tradition dates back to 1416, when, during the Council of Constance, a group of three scribes decided to go to the St. Gallo Monastery, where one of them, Cencio Rustico, found one of the most important publications in architectural history, the "De Architectura" by Vitruvius (Tiraboschi 1787).

However, during this period there was a sudden and great interest in the most well-known minds of the Renaissance, even in the humanities, in relation to the Vitruvian manuscript. More importance was given to Books IV and V of "De Architectura", where the description of the Architectural Orders is located. Consequently, the architectural orders and the classical proportions took off once more and started again to be a major element in architecture also due to the contemporary and increasing interest in archaeological sites. As a matter of common knowledge, the few drawings that Vitruvius attached to the manuscript were lost during medieval transcripts, due to the lack of drawing ability of the Benedictine monks. This difficulty combined with an unclear Latin language contributed to the birth of many different interpretations of the Architectural Orders. The architects who approached this doctrine elaborated personal theories that materialized with the creation of ever-changing artefacts and the writing of a multitude of great authors' treatises on this subject.

A detailed analysis of some of main Orders treaties, in particular the works of Vitruvius, Alberti, Vignola, and Palladio, highlighted the need to create a unified genesis of the Orders' interpretation so as to create a single model that could be applied to the different, well-known versions. Since survey is an important part of this process, the aim was to define a new way of representing the five orders that could be useful for the preservation of ancient artefacts.

Having basic, easy-to-modify models could speed up the stage of graphic restitution of real artefacts,

Figure 1. Rhinoceros and Grasshopper logos.

thus improving the heritage cataloguing system. This study could also be helpful in the critical survey phase. The possibility of having the representations of those models idealized by the treatises to compare with real cases, could allow for making assumptions about certain elements, like the author's identity and consequently getting, for example, information about the construction techniques used and the construction process of the entire studio. These data are fundamental in the case of restoration and consolidation of the analysed artefacts, enabling the design of an intervention that is as consistent as possible with the original identity of the work (Docci 2009).

The same process could be extended to a wide range of case studies. A series of factors may be investigated, such as the growth process of an urban centre, the use and development of different categories of buildings, the progress of construction techniques, and others.

The Instrument

The classical meaning of the term "Architectural Order" groups together the compositional and proportional rules named as Order and Symmetry, wherein elements are simultaneously dependent on the overall system and the individual parts. These notions define the orders for the algorithm and digital tools. Specifically, generative modelling seems to be the best way to reach the goal.

Normal 3D modelling allows for the creation of models which transmit only an image. This is measurable in all its parts but does not give any information about the graphics rules and the process used by the designer. However, the result of generative modelling is an element that contains various information. In addition to the traditional 3D image, the designer may also produce a representation of the generative algorithm, which could be considered a "representation of the representation".

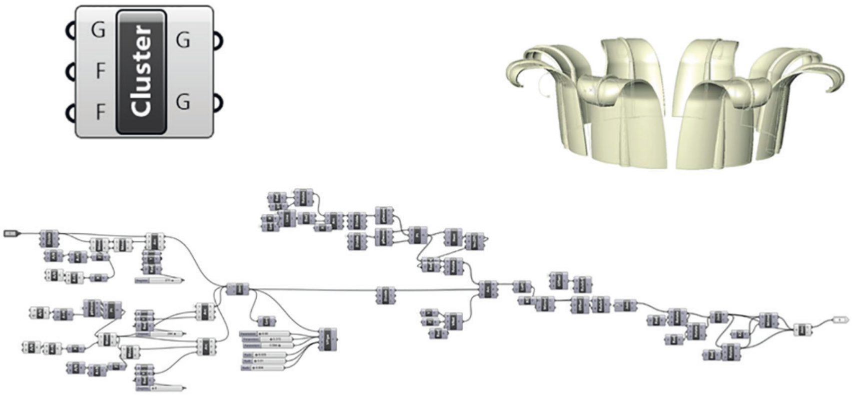
The results of generative modelling are comparable to a treaty, as the model contains both the rules and the final object. Moreover, the algorithms could be continually adaptable and can evolve into countless new forms as a digital tool to create a family of objects with similar features (Davis et al. 2011). The models of this project have been developed with the software Grasshopper. Grasshopper is a Visual Scripting add-on developed for one of the most popular 3D modelling programs, Rhinoceros (Figure 1). In short, Grasshopper is a free scripting visual editor designed to make program knowledge unnecessary. Due to an intuitive graphic approach based on a knot interface, the users can develop a set of instructions that are translated into a 3D model in the Rhino window.

The algorithm is a way of troubleshooting, to compute a path leading to the final solution from the question and the initial information. The process of the algorithm leads to a set of instructions that when repeated (always with the same input data) give the same result (Tedeschi 2010). The Grasshopper algorithms (Figure 2) are like a knots diagram where every knot is an operation that matches a geometry only after the application of input parameters. In the Rhino interface, the operation could be linked to others, creating a web of mutually dependent operations. Changing one of the inputs gives a different result and a different geometry, known as "Parametric Modelling." That is why, once the five Orders algorithm was designed, it has not been difficult to translate it into the different authors' versions. The possibility to define a general procedure has resulted in a common genesis for the Orders, and at the same time allows for the determination of the main differences.

The Orders' General Rules

This project studied the following Orders' Treaties: the "De Architectura" by Vitruvius, the "De re aedificatoria" by Alberti, the "La regola delli cinque ordini d'Architettura" by Vignola, and the "I quattro libri dell'Architettura" by Palladio. The aim was to give general rules regarding proportions within the architectural orders. Starting from their works, it could be quite easy to find the thickness and the ledge of every part. The column diameter at the bottom is the key measurement and determines all the other dimen-

Figure 2. Algorithm view in Grasshopper.



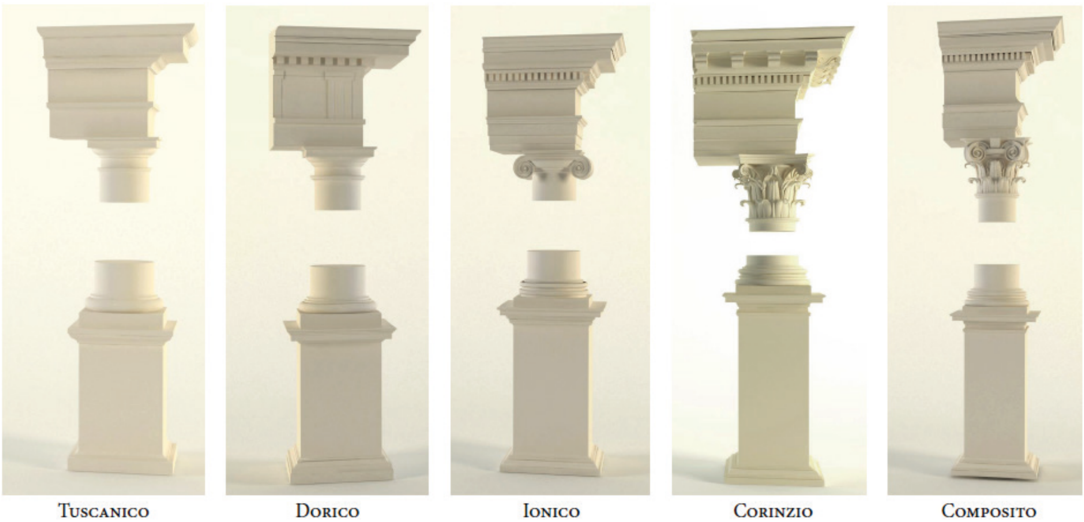


Figure 3. Column models from Vignola.

sions. Such a practice allows the designer to make a representation unlinked to the metric system used. This is the idea that has always charmed architects.

The rules of proportion could be summed up in three different groups: 1) the following partitions process; 2) the submultiples process; 3) the decimal metric process.

The first process takes every dimension from the previous ones, used by Vitruvius, Alberti and Palladio. This process has considerable benefits in the context of hand drawing and considering the elements final shape. The submultiples process, used by Vignola, divides the radius at the column base into a number of smaller parts, like submultiples. This operation, in case of hand drawing, could be very difficult, but allows for a very accurate representation. Vignola intermixed both of the processes. Fixing the proportion 4:12:3 between pedestal, column, and trabeation, he dimensioned every single element through the radius division (Migliari 1991) (Figure 3).

The final process, the one used by Chitam, is the most criticized, as it is the least practical. He defines every element separately, eliminating all of the links to the whole construction, thereby going against of all the compositional process of the architectural orders (Migliari 1991). In this project, the models, as the algorithm, have been built following the Vignola process and later, thanks to similitudes, converted to the others version.

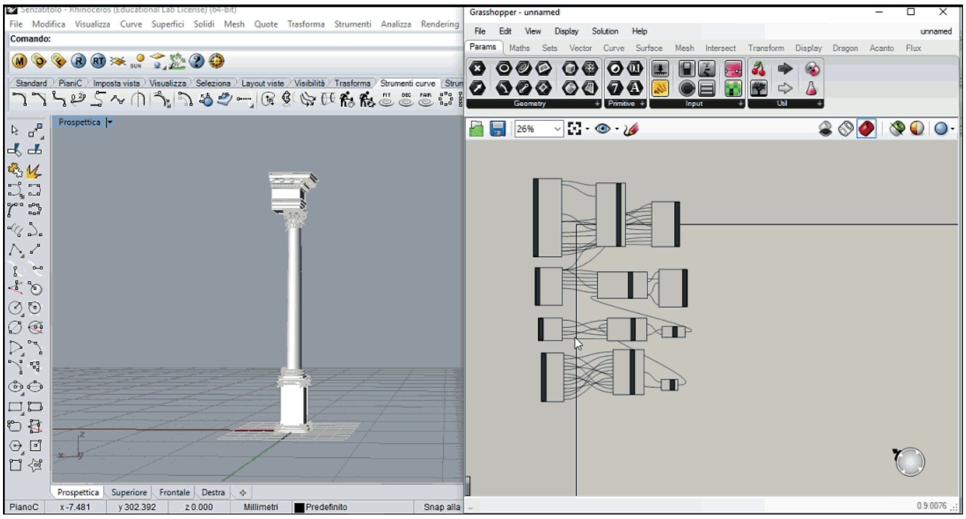


Figure 4. The modelling of a column.

Modeling

Modeling architectural orders begins with generating the smaller parts of these elements, the moldings that are like letters that compose the words that generate the sentences (Morolli 2013). Different combinations of moldings give different parts. The moldings were created by putting the generative algorithms in clusters. This Grasshopper function allows for slimmer, final algorithm-composed clusters that work as independent tools. So, the final algorithm of the entire order can be seen as the positioning of the various clusters of the moldings opportunely scaled. The moldings (analyzed as indicated above) are the torus, the canaliculus, the gulula, and the undula. In the case of the listellum, it has been generated only by a rectangle extrusion. Clusters have been used also for decorative elements with more complicated geometry, like the Corinthian capitol parts. In this case, there are clusters for inferior leaves, the caulucoli, the modiglioni in the Corinthian trabeation, and Ionic dentils. It must be said that some particular geometries – like the Corinthian volute, capitol, and base – were first drawn using Rhino and then via Grasshopper (using an internalized tool) (Figure 4).

This workflow has generated a common skeleton with all the geometries repeated in every element, linked time after time to measures or elements typical of every order. The smaller decorations compose the larger parts of the base, the column, the capital, and the trabeation. Each of these clusters was placed into another cluster.

All the features that diversify the Order versions have been identified and linked to the major clusters. These inputs of various kinds, numeric or geometric, have resulted in new clusters divided by author. The entire system is linked to a numeric tool that determines the diameter dimension of the column base. To compare a model and a real artefact, we input the real diameter dimension using the numeric tool to have a model in the right scale. It is also possible to change the heights of all the elements to the real dimensions in order to have a model that is most similar to the real artefact. If we have a mechanical way to model the Architectural Orders, we can have measurable representations without deep knowledge of modelling and proportional rules (which can serve as an instrument usable by everyone).

The Comparisons

It was possible to create four different models for each Order starting from the same algorithm. These models then generated the comparison pictures to emphasize differences in shape and geometry between each author. For example, the lack of the Vitruvian Composite order is because of the death of the author before of the birth of the Order. This Order - with the Tuscan one before it - is a Roman creation and represented the fusion of the Ionic and the Corinthian Orders. Furthermore, the Vitruvian Orders do not include pedestals in the Greek manner. The same characteristics are also in

Figure 5. The Doric column modelling.

a version by Alberti, who blindly followed the Vitruvian rules.

There are, however, additional differences with respect to Alberti. He does not describe the Tuscan Orders and he has different types of decoration specifically in the Corinthian and Composite capital (De Paoli 2011). The other authors have two kinds of folia. The prima folia is half the height of the secunda folia and both start from the bottom of the cylinder. Alberti draws the secunda folia like the prima folia with the same dimension and puts them over the finish of the prima folia. Alberti, also does not have Culiculum, but only Helices that he calls medium cauliculi. He also uses a different geometry to represent the volute, a theme that would be worth studying further.

After these general considerations were carried out in a dimensional studio, every column was matched with a thickness table to compare the different versions and simplify the drawing.

The Applications

Aiming to show the capabilities of this project, we decided to develop three of the many possible applications:

1. Graphical rendering of an existing historical artefact.

2. Reconstruction of a historical artefact by the only remains.

3. Export of parametric models from Rhinoceros in Revit, and next generate a family of elements.

Graphic Rendering of an Existing Historical Artefact

The first application comes from the survey. Taking

Figure 6. The Ionic column modelling.

a few measurements, you are able to generate an accurate digital model of the reality. In choosing the most similar model to the real case, it is necessary to change some value of the algorithm, like the imoscapo radius (the circumference at the base of the column) and the final height to obtain a full graphics restructuring.

We chose to study the columns of St. Peter's Cortile delle Stelle in Perugia (Figure 5), designed by the architect Galeazzo Alessi (Perugia 1512 - Perugia 1572), a contemporary architect of two of the treaties analysed in this project, Palladio and Vignola. The square courtyard is surrounded by Doric columns, the subject of the first application we developed. The technique of photo-modelling was also used, which allowed us to realize a 3D model in real scale in order to measure the highest parts. Photo modelling is a useful and fast tool, but in this case, it did not produce complete results.

The column is an object of considerable size and full of details. Without more sophisticated instrumentation, it was not possible to obtain an accurate survey in all its parts. A digital representation is possible; however, the image-derived point cloud would require significant postprocessing by a subject-matter expert in order to product accurate measurements. The product of this project aims to provide an instrument that follows the rules of classical architecture so as to skip the reprocessing phase.

Reconstruction of a Historical Artefact of Which There Are Only Remains

The second application was to create a hypothetical reconstruction of a column from its ruins. The starting element is an Ionic capital, from the Museo Civico Archeologico e Pinacoteca Edilberto Rosa of Amelia, of late Republican age, which presents an almost intact echino. The volute, even if damaged, still indicates the form, and it appears to be very close to Vignola's one. The channel of the volutes, below the abacus, is completely absent. This case is not reported by any of the analyzed treatises.

It may be thought that the element indicated, by the museum specification, as abacus may instead be the volute channel. But this is only a hypothesis.

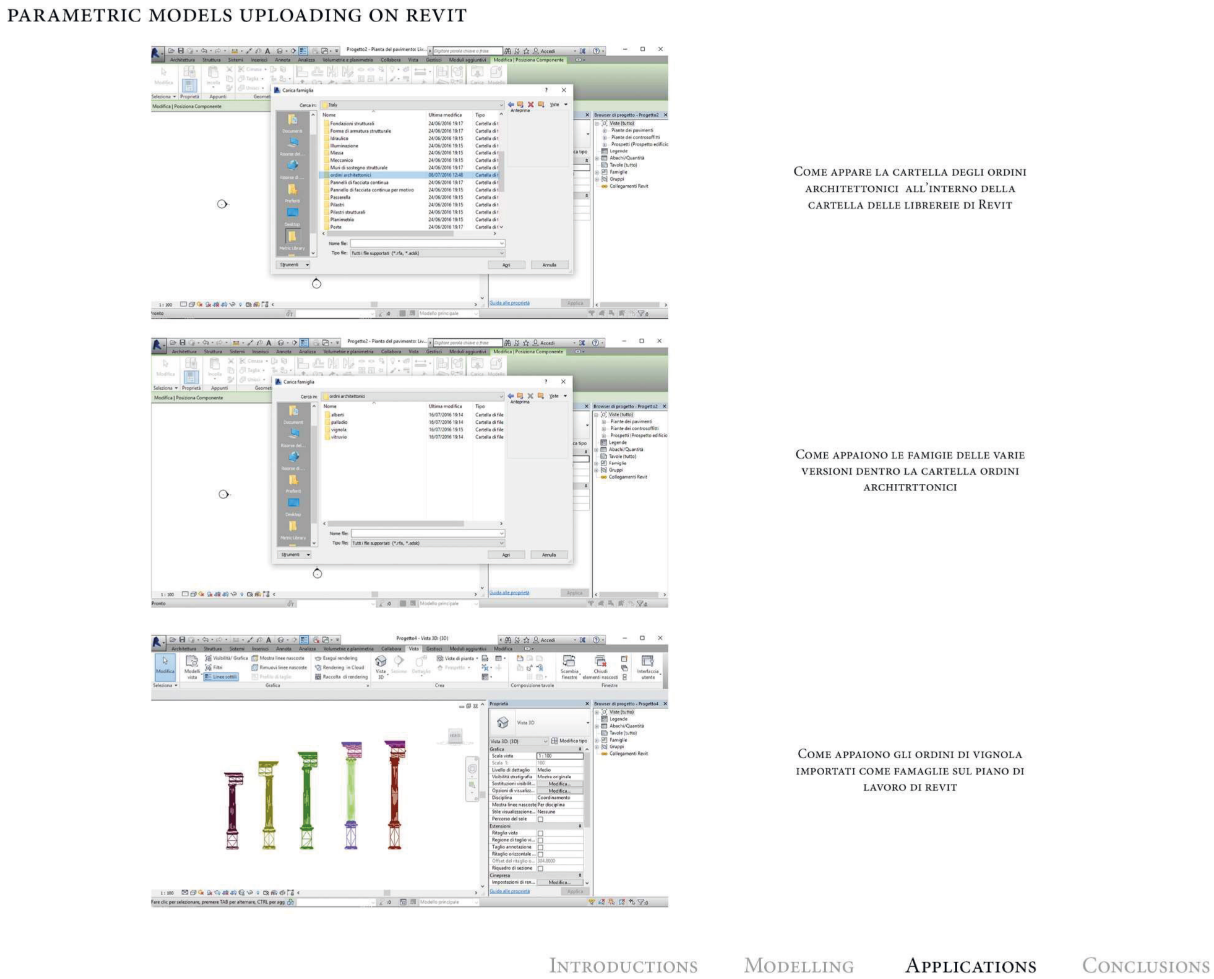


Figure 7. Columns view on Revit.

In the interest of providing more information, both hypotheses have been brought forward.

Moreover, two models were created: one with and one without the channel of the volutes, maintaining the unaltered propositions. Again, we made use of the technique of photo-modeling take measurements without touching the artifact. The 3D model was developed with the Vignola model, applying the appropriate changes in the case of the capital without a channel (Figure 6).

Export of Parametric Models from Rhinoceros in Revit

Revit Architecture is a widely distributed program and, as the central instrument of BIM, its use is growing. The transfer of the model of the Order into Revit has potential important benefits. It enables the parameterization of the models, because the creation of parametric elements in Revit is the center of the system and all its applications. On the other hand, it expands the power of the BIM to the aspects of measurement and to the parametric study of the history of architecture.

Revit is a numerical modeler and it reflects the information as numbers and equations while Rhinoceros is a NURBS modeler and the elements are not always easily transferable. It is necessary to convert the Orders models to polyline to export these in Revit. The new Revit family was imported choosing the character of a Generic Model Metric. This operation was repeated for all the orders and for all the different models of the different treaties, creating a new Directory in the Revit Library containing all the new families (Figure 7). This is demonstrative of how it is possible to create new Revit elements, which are potentially loadable online for widespread distribution. In a hypothetical study and measurement of a historical artifact with Revit, the presence of libraries containing all Orders by the various treaties could be advantageous to study, research, and comparative operations.

Conclusions

This project led to the consultation of multiple sources and the implementation of the rules derived from them. The five algorithms for the representation of Vignola's orders have been defined in the first part of the project, and then these scripts have been modified to determine the algorithms that were adaptable to the different versions. Finally, the algorithms have been discretized and organized with the clusters to simplify the modeling process.

What we have created is a tool to create accurate products from a few key measurements usable also by someone without deep architectural knowledge. In a practical way, the results of the studies of four of the oldest and most important architectural treatises, resolve some problems linked to the difficulty of the representation of the Orders. The proposed models also allow us to make a comparison with actual artefacts and to hypothesize what treaties inspired the author, and to deduce the identity of the architect and the period of construction.

The algorithm actually has broader applications, as the results can also be used in the reconstruction of now lost elements. Additionally, this process could lead to potential developments in archeology. This study could be expanded to the architectural rules of classical buildings, so one can develop, from the remains, a plausible digital representation of the entire construction.

References

Davis, D, Pallett, J, and Burry, M 2011 Understanding visual scripts: Improving collaboration through modular programming. *The International Journal of Architectural Computing*, 9(4): 361-375.

De Paoli, M 2011 *Il disegno degli ordini architettonici. Letture degli elementi connotative*. Calcinato (BS): Acherdo.

Docci, M and Maestri, D 2009 *Manuale di rilevamento architettonico e urbano.* Roma: Laterza

Migliari, R 1991 Il disegno degli ordini e il rilievo dell'architettura classica: Cinque Pezzi Facili. *Disegnare idee immagini*, 2: 49-66.

Morolli, G 2013 *La lingua delle colonne: morfologia, proporzioni e semantica degli ordini architettonici, Studi e documenti di architettura e della citt*à. Firenze: Edifir.

Tedeschi, A 2010 *Architettura parametrica: introduzione a Grasshopper.* Brienza (PZ): Le Penseur.

Tiraboschi, G 1787 *Storia della letteratura italiana del cav. abate Girolamo Tiraboschi ... Tomo 1. [-9.]: Dall'anno 1400. fino all'anno 1500*. Modena: Società Tipografica.