Interactive Tabletops for Architectural Visualization

Combining Stereoscopy and Touch Interfaces for Cultural Heritage

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This paper presents an interactive apparatus to didactically explore Alberti's treatise on architecture, De re aedificatoria, as generative design systems, namely shape grammars. This apparatus allows users to interactively explore such architectonical knowledge in both appealing and informal ways, by enabling them to visualize and manipulate in real-time different design solutions. The authors identify the difficulties on encoding the architectural knowledge of a parametric design model into an interactive apparatus to be used by laypeople. At last, the authors discuss the results of a survey conducted to users that interacted with the prototype in order to assess its ability to communicate the knowledge of an architectural language.

Keywords: *Alberti, generative design, multi-modal interfaces, shape grammars, user experience*

INTRODUCTION

This paper presents an interactive apparatus to didactically explore Alberti's treatise on architecture, *De re aedificatoria* (Alberti, 2011), as a generative design system. This work belongs to a wider project, Alberti Digital, which aims to determine the influence of *De re aedificatoria* on Portuguese Renaissance architecture, making use of a computational framework.

We chose to hermeneutically explore the treatise descriptions on sacred buildings and *columnatio* systems by inferring the underlying structure provided by description grammars and shape grammars (Stiny and Gips, 1972).

A synthesis of the project outcomes was shown as an exhibition, firstly presented in April 2013, at the Science Museum, University of Coimbra (Figure 1). The exhibition focuses not only on the results achieved, but also on the tools used, and on their development.

It also features a semi-immersive environment to pedagogically present the knowledge inferred in defining the shape grammars. This interactive apparatus allows us to explore the architectonical knowledge described on the *De re aedificatoria* in appealing and informal ways, by enabling the visitors to visualize and manipulate in real-time different design solutions generated interactively.

Simultaneously, the semi-immersive table facilitated the comprehension of the combinatory, algorithmic and computational nature of Albertian architectural theory, by highlighting explicit relationships between the generative model outcomes, as well as the morphology and proportional variations prescribed in the treatise.

Figure 1
Alberti Digital exhibition, Science Museum, University of Coimbra, April 2013 (photo by Do Mal O Menos)

METHODOLOGY

The *De re aedificatoria* descriptions offer enough knowledge to define an architectural language and a grammar, expressed in algorithmic terms. Accordingly, the initial stage of our research included four steps (Figure 2). Since the treatise only contains textual descriptions, our initial task was to read and select parts of the text describing the architectonic components from the *columnatio* systems and the temples. The second task was to gather and group the information into parametric schemas that interpret those descriptions. This information can be encoded into a grammar that, through the application of its rules, generates a corpus of solutions that follow the treatise's architectonical rules. Finally, translating the grammars into a parametric computational model allows us to visualize the resulting structures.

We developed an interactive setup to explore design space prerogatives of the treatise in a fashion accessible to laypeople. We devised a tabletop prototype to explore 3D virtual models of existing buildings in stereoscopy, as if they were physical models lying above the tabletop (Figure 5). We also introduced the possibility of customizing an entire model of a temple according to the rules in our Alberti shape grammar.

DESIGN DESCRIPTIONS AND DESIGN COMPUTATION MODELS: DIDACTIC TOOLS TO CLASSICAL ARCHITECTURAL KNOWLEDGE

Establishing design principles can be a complex process, it involves (self) arguing and defining rules of design, using different areas of knowledge (geometry, physics, economics and social sciences, etc.). The tradition of classical architecture is an example of this feature where standard systems of naming and segmentation contributed to establish a conceptual framework and its architectural principles. According to Mitchell (1990, p.24), this requires a vocabulary large enough to differentiate parts, symbolic and functional relationships that enable specifying properties and interrelations of different parts in the design. This vocabulary can either be expressed by assigning values to variables of a data structure, or by a set of logical principles and their notations, or even through a textual description written in natural language

Simultaneously, computation can be understood as a series of rational, logic, algorithmic, deductive and inductive processes, whose structure and systematization explores the possibility of ob-

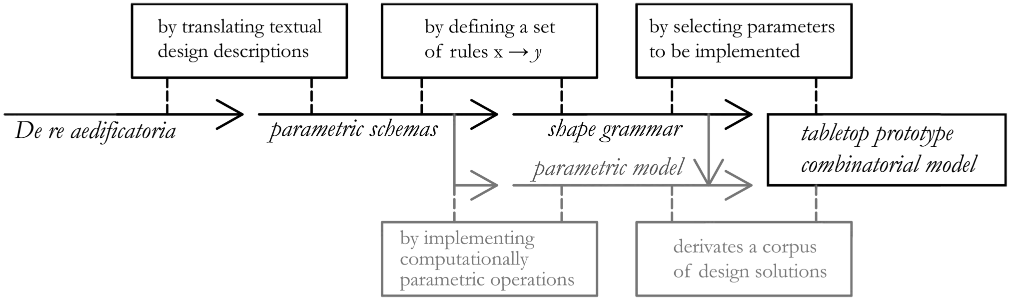


Figure 2
Diagram representing the steps taken to understand and decode the treatise

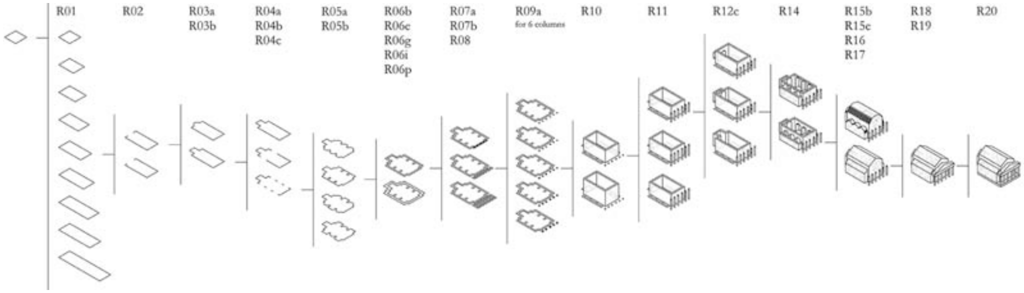


Figure 3
Computation tree of the temples shape grammar: to each step of the computation, by the application of a rule, are visible the possible transformations for the specific left side shape of the rule. (Figueiredo et al, 2013)

taining solutions to a given problem. Although eminently abstract, these structures allow to relate knowledge obtained through cognition, simulation and intelligence-based rules, among others.

This research took into consideration the idea that design descriptions and computation are both transversal tools to engage an architectural design and subsequent language of design. In order to communicate this principles to a wider public, most of the times codified in representations that only architects understand, we have proposed an exhibition setup that helped the visitor to grasp the architectural principles inscribed in *De re aedificatoria*. The layout of the interactive stereoscopic visualization apparatus was structured to explicit the computational and combinatory relations synthesized in the shape grammars and their generative outcomes.

GENERATIVE SHAPE GRAMMAR'S IN ACCORDANCE TO ALBERTI'S THEORY

Since the treatise has no graphical information, our first task was to read it and to systematize knowledge that led to the understanding of the column systems and temples architectonical principles. Graphical notations were drawn from the translation of our interpretation of the text. These notations led to the definition of a set of parameters and conditions which allowed for the development of a system of schemas, useful to set algorithms that inform both the shape and proportions from each part and the relations between the parts of the buildings and their interrelated proportional features.

Departing from this knowledge, a set of shape rules were defined to compose a *columnatio* systems generative shape grammar and a rectangular temples generative shape grammar. In both grammars, by applying their shape rules in a step by step computation methodology, are generated design solutions within the same language. Figure 3 illustrates this process, a computational sequence, where different options are shown after the use of each rule of transformation, but only one is subsequently transformed by the use of the next rule, finally resulting in a design solution for a rectangular temple.

Based on the developed shape grammars, and in order to test them, parametric models were developed in a visual programming interface, implemented into computer programs that automatically generate digital models in a CAD application, according to input parameters (Figure 4). This framework allows for real-time visualization of the results of varying parameters. These parametric models are highly detailed and compliant with Alberti's prescriptions encoded in the shape grammars (Figueiredo et al, 2013), and they served as a direct basis for the development of the virtual reality tabletop application.

INTERACTIVE STEREOSCOPIC VISUALIZATION OF ALBERTI ARCHITECTURAL MODELS: A DIDACTIC TOOL TO COMPREHEND A GENERATIVE DESIGN SYSTEM

The technological advances that have been witnessed in the last few years allowed the development of new and more interactive applications for all kinds of scenarios. Multi-touch devices and depth sensors like Microsoft´s Kinect are clear examples of these advances, allowing both non-intrusive and inexpensive user tracking. As for visualization, common 3D displays allow users to perceive imagery as if it popped outside the screen. This motivates a fresh look at tabletop interfaces, towards better support of 3D direct manipulations in scenarios until recently conceivable in the realm of science fiction.

Exploiting the aforementioned technological solutions, we developed a tabletop prototype (Figure 5) that consists on a semi-immersive environment based on a stereoscopic multi-touch surface combined with a Microsoft Kinect depth camera. This camera (E) tracks the user's head, enabling a real-time personalized 3D perspective view of the contents shown on the table. While a user moves around the table, the perspective view of the building changes according to his or her movement. A 3D television set (D) combined with a 3D active shutter glasses (B) enables stereoscopic visualization, sending 1920x1080 pixel resolution images to each eye 60 times per second. This setup allows rendering high definition virtual objects as if they were lying above the table surface. The touch-enabled surface, using a multi-touch frame (C) capable of detecting up to 10 touches, allows interacting with virtual models through gestures.

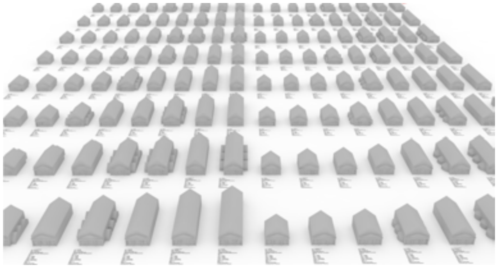
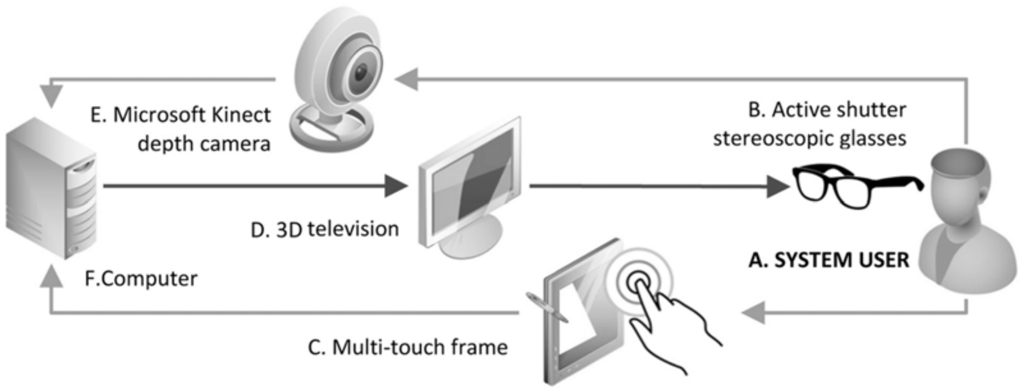


Figure 4
Sample of design solutions generated by the temples parametric model.

Figure 5
Tabletop prototype hardware setup

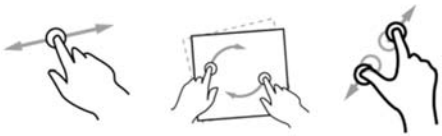
With this semi-immersive environment, users can explore 3D virtual models of buildings using both hands. To manipulate the content on the stereoscopic surface the visitor can use several touches to interact with each model at a time. We developed a finger-cluster interaction method, which allows users to move, rotate and uniformly scale the models. By dragging the fingers anywhere along the surface, the model will move in the direction of their movement.

Figure 6
Tabletop prototype operating diagram



To rotate the model along the axis perpendicular to the surface, people need to apply a rotational movement via at least two fingers, but they can use their entire hand if they want. By changing the relative position of all fingers a user can uniformly scale the object. If the distance between the fingers and their center changes, the model scale will increase or decrease accordingly. This technique uses the well-known algorithm Rotate-N-Translate (Hancock et al., 2006), available in almost every modern multi-touch device (Figure 7).

Figure 7
Possible interactions through touch: translation, rotation, and scaling



FROM PARAMETRIC MODEL TO THE TABLETOP INTERFACE

By means of this environment, users can explore 3D virtual models of Alberti buildings. In addition, we included a special model, which is a temple that supports different types of customizations, accordingly to the shape grammar extracted from the *De re aedificatoria* treatise

Similarly to what the generative shape grammars support, the interactive prototype simulates parametric variations on generated solutions by considering certain proportional, morphological and stylistic attributes in detriment of others, allowing the user to choose, under certain restrictions, the shape rules to be applied.

The tabletop prototype, allows people to select different shape rules using a button-based graphical user interface (GUI), which controls certain features of the temple model (Figure 8). Each feature combines specific parameter(s) and condition(s), which can be changed within a pre-defined set of values, represented by mutually exclusive toggle buttons. For each feature, only a button can be activated at a time, and some buttons might be disabled depending on selected features. For example, the number of pairs of lateral chapels that compose the temple is a feature, whose values can vary between 0, 1, 3 or 5. However, if the cell proportion (another feature) becomes smaller than 3:1, measuring the relation between the length and the width, the button with value five will be disabled (Figure 8, D) since this proportion does not accommodate five pairs of lateral chapels along the longitudinal inner facades.

The set of customizable attributes, or features (Table 1), is divided into three modes, related to three aspects of the temple (Figure 8, A), namely the composition of the *columnatio* system (Figure 8, B), the arrangement of the portico located in the main facade

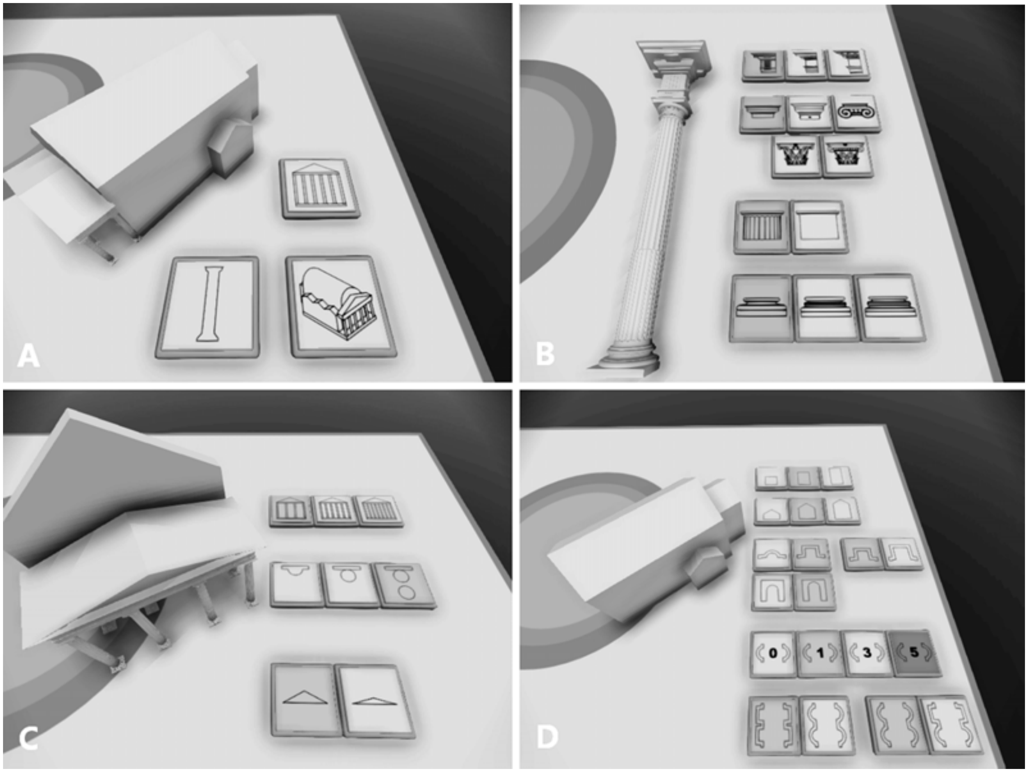


Figure 8
Temple customization: menus (Fonseca, 2013)

(Figure 8, C), and the temple itself morphology and proportions (Figure 8, D).

The main architectural knowledge on temples that Alberti encoded in his treatise translates to the three modes of interaction. Although discrete, they establish interrelations between each other, thus framing an overall architectural language. Different combinations from the *columnatio* system parts will affect the portico definition as well as the dimension of the cell, tribune and chapels. Simultaneously, changes to the cell proportions will constrain the width, height and depth of the portico

The layout of the interface was designed to provide people (museum visitors) with a clear understanding that, by manipulating one architectural feature, other characteristics will be affected, as well the overall expression of the building, thus affording a better, clearer exploration of the Albertian design space by laypeople.

This network of proportional and morphological dependency represents to a certain extent the idea of *concinnitas*, the basic principle of the Albertian thought, described by Rudolf Wittkower (1973, p.33) as embodying the classical idea of maintaining a uniform system of proportion throughout all parts of a building.

FEEDBACK FROM USERS

The objective of developing such a prototype was to present an architectural language in a way that

Table 1
Temple customization: features

HOME (A)	Column mode (B)	Portico mode (C)	Temple mode (D)
Column mode	Type of entablature	Number of columns	Length of cell
Portico Mode	Type of capital	Portico arrangement	Height of cell
Temple mode	Type of shaft	Height of pediment	Shape of tribune
	Type of base		Size of tribune
			Height of tribune
			Number of chapels
			Shape of chapels
			Alternance of chapels

would engage the exhibition visitors, providing an experience different from the traditional exhibition media. In order to assess the success of this initiative, a survey was conducted to users that interacted with the prototype, in which they could express their opinions about that experience. The survey was conducted to 27 people, with ages over 19. More than half of the users were between 19 and 24 years old, and two thirds hold a Bachelor degree or higher.

From such survey, which consisted of closed Likert-scaled questions, we were able to gather information to conclude the following:

- The prototype aroused the immediate curiosity of 62 % of visitors, leading them to experiment with it right away.
- 54% of visitors felt that the application interface was easy to use, and only one visitor could not understand how it worked.
- All visitors agree that the prototype undoubtedly enriches the experience of the museum exhibition, and also agree that this type of experience can be interesting when applied to other exhibitions.
- The interactive table provides an engaging and innovative experience for visitors, thus enriching the exhibition. The visitors agree that such an experience is more interesting than the models and posters also presented at the exhibition.
- The application enables the visitors to visualize the buildings in 3D through stereoscopy, and they agree that it enriches the experience. Only 18 % of visitors did not realize that while moving around the table the perspective view of the building changed according to their movement.

We can say that the interactive system was successful as a didactic tool, able to convey a specific architectural heritage - architectural knowledge described in the *De re aedificatoria* - by allowing users to explore the system generative outcomes within their vocabulary and syntax content.

CONCLUSIONS

In implementing Alberti's models into the tabletop prototype, two main difficulties arose. The first difficulty was technological: the application running on the tabletop prototype doesn't match the generative capabilities of the shape grammar formalism, nor of the corresponding parametric model. The solution space generated by combining all the parameters in the original models proved too complex to be implemented into the prototype's application. This fact forced the selection of a number of parameters smaller than the ones available in the original shape grammar and parametric model.

Nevertheless, supposing that all the parameters could be implemented, the control of such an extensive solution space would require an equally extensive - and complex - user interface, forcing the use of even more modes, with more sets of features, and probably rendering the experience very little engaging to the user.

Therefore, the second difficulty was a cognitive one. This emphasizes the need to focus research not only on pushing the technological boundaries of generative design systems, towards the ability to model and visualize more accurately and with more detail, but also on synthesizing the complexity of the Albertian thought in order to communicate their essence to a non-specialist audience.

Current research is pursuing a system that can provide an even deeper engagement of the user. On one hand, tools are being developed that overcome the technological constraints that conditioned the interface for the presented prototype. The objective is to extend the manipulation of geometry beyond the combination of objects, towards parametric and rule-based real-time modelling. On the other hand, such modelling is intended to be as user-friendly as possible, taking into account both the cognitive and ergonomic characteristics of the average user. By combining techniques such as virtual reality, motion capture and shape grammars, we aim towards a new generation of interfaces that allow for a smoother interaction between designers, namely architects, and their creations.

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