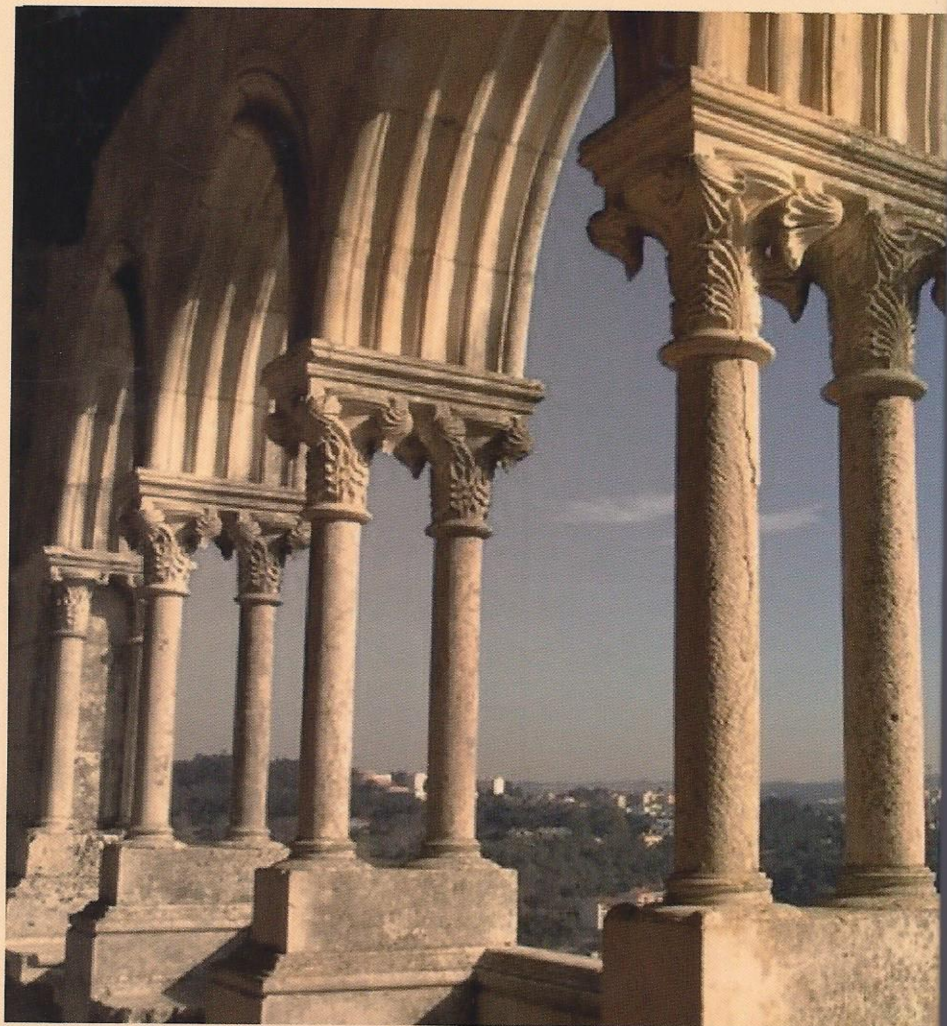

High Value Manufacturing

ADVANCED RESEARCH IN VIRTUAL AND RAPID PROTOTYPING

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Hand-held 3D scanner without sensor pose tracking or surface markers 429
J. Kofman & K. Borribanbunpotkat

Calibration of a hand-held multi-line laser-camera 3D scanner 435
K. Borribanbunpotkat & J. Kofman

Error compensated camera-projector calibration in shape measurement 441
D. Li & J. Kofman

Interaction in an immersive multi-projection system based on light wand like devices 447
C. Oliveira, H.M.C. Vale & A.J.V. Porto

Reference 3D-tumour models from CT-data for evaluation of contouring algorithm based on the PET/CT imaging 451
I. Jonuschies, K. Broekel, J. Kurth & B. Krause

Automatic cutting edge detection for a cylindrical mill 457
G. Moroni & S. Petrò

Process chain for design, optimisation and production of open-porous lightweight structures 463
P. Sembdner, R. Weggässer, C. Schöne & R. Stelzer

A tool for computer-aided orientation selection in additive manufacturing processes 469
A. Armillotta, M. Cavallaro & S. Minnella

Innovative developments on Agile-CAD system 477
M. Gaspar, N. Alves, N. Martins-Ferreira & P. Bártolo

BioFab toolbox – Software tools for biofabrication 483
N. Alves, P. Bártolo, N. Ferreira, M. Gaspar & A. Mateus

Non-invasive image technologies and biomimetic research applied on the design of innovative projects 489
J.R. Lopes dos Santos

Architecture and parametric design: A prototype for a kiosk 493
L. Mateus, F. Roseta & F. Vaz-Monteiro

Nano CAD design of scaffolds based on triple periodic surfaces 497
H.A. Almeida & P.J. Bártolo

Simulation and virtual environments

Additive manufacturing and topology optimization to support product family design 505
N. Lei, S.K. Moon & G. Bi

On a three-dimensional Lattice Boltzmann Model of droplet impingement for ink-jet deposition 511
W. Zhou, D. Loney, A.G. Fedorov, F.L. Degertekin & D.W. Rosen

Heat transfer modeling in fused deposition techniques 519
F.M. Duarte, S.F. Costa & J.A. Covas

Structural and modal analysis of a desktop 3-D printer considering an interchangeable mini screw extrusion head 525
G.dos.S. Ribeiro & Z.C. Silveira

Human cranium biomechanical simulation 531
P. Perestrelo, P. Bártolo, M.P. Torres, P. Noritomi & J. Silva

Development of an ontology-based knowledge methodology in product innovative collaborative conceptual design environment 537
S.-J. Liang

Integrating shop-floor virtual environments with real machining cell data 543
H.M.C. Vale, C. Oliveira & A.J.V. Porto

The disclosure of the BIM concept in civil engineering training 549
A.Z. Sampaio

High Value Manufacturing – Bártolo et al. (Eds)
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Architecture and parametric design: A prototype for a kiosk

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ABSTRACT: This paper describes the application of the visual programming interface Grasshopper, which runs in Rhinoceros software, in the architectural design of a prototype for a kiosk. The concepts supporting the architectural approach encountered four problems which required innovative design tools: 1) the kiosk was to be built in renewable materials, mostly cork; 2) the kiosk was to be repeated in different locations, each outcome with a similar generative topology, but a different shape; 3) the inner surfaces of the kiosk were curved and had to be divided into a stereotomic pattern; 4) the stereotomic pattern had to be subdivided into individual irregular smaller components. In conclusion, the paper describes how the challenges arising in the design stages were overcome with parametric modeling tools. The kiosk is currently in the construction stage and the challenge yet to overcome is the irregularity of the individual components.

1 INTRODUCTION

1.1 *The challenge: Architectural practice and parametric modeling*

How will the practice of architecture be affected by parametric modelling? "Parametricism is the great new style after modernism [. . .] Parametricism is ready to go mainstream." stated Patrick Schumacker (2010), author of several writings on parametricism and partner at Zaha Hadid Architects. The complexity inherent to architectural practice should indeed have much to gain from possibilities of parametric design; nevertheless, today, architectural practices in Portugal remain distant from the technical and creative paths opened by this design approach. This paper describes how a commission to design a prototype of a kiosk became an opportunity to explore parametric modeling within the Portuguese construction sector.

The architectural practice *Roseta Vaz Monteiro Arquitectos* was invited to participate in the commissioned to design a prototype for a kiosk which had to be adaptable to similar functional situations, but different physical locations. The idea was to design an architectural object which could be easily repeated with a parametric generative topology which did not, necessarily, reproduce objects of the same size or shape. The need for repeatability, along with an intended architectural expression with inner curved warped surfaces, made it difficult to adopt a traditional design methodology. It became clear that a parametric design approach would be best suited.

In traditional modeling, it can be relatively easy to generate a single solution for a specific problem; however, as complexity increases, requiring changes to test different hypotheses for a solution, modelling becomes a time-consuming job. As indicated by Woodbury (2010), when the model does not change automatically, the need to change a simple length may lead to several hours modelling. These are also the limitations of using physical models. Parametric modeling, on the contrary, presents a solution for this kind of problem. As defined by Schumacker (2010): "Parametricism implies that all architectural elements and complexes are parametrically malleable."

Initially, in architectural practice, computers were relegated to mimicking existing procedures, performing these with greater efficiency. Today, parametric design presents a new path to conceive architectural spaces combining unprecedented creative freedom of form-finding with high efficiency in the final definition of both tender documents and cost estimates; thus, broadening the architects' ability to intervene effectively, as related by Kwinter (2010). As Mitchell & McCulough (1995) best state in one of the chapters of Digital Design Media, a seminal book about the use of computational media in the context of architecture: "New tools and new thinking go together".

1.2 *The software: Choosing the tools*

The possibilities offered by parametric modeling include tools which can provide solutions related to families of architectural elements, such as wall or window types and can also provide tools which offer a visual interactive interface, allowing the architect to explore the process of form finding quickly regardless of the variety and range of forms.

In the first case, tools which provide families of architectural elements can be found in software like ArchiCad (http://www.graphisoft.com/archicad/) or Revit (http://www.autodesk.com/products/autodesk-revit-family/overview). The effective use of such tools enables the relation between the tender documents and the model to be systematically updated; thus, introducing efficiency and reducing the margin of error in both design elements and cost-estimates.

For this paper, we are considering the second kind of tools, which enable the architect to explore the process of form finding, quickly translating sketched ideas into parametric shapes. We are referring to tools like Vasari (http://autodeskvasari.com/) for Revit or Grasshopper (http://www.grasshopper3d.com/) for Rhinoceros (http://www.rhino3d.com/). The freedom provided by such design tools is only effective if supported by consistent knowledge of geometric and mathematical concepts, as the first step to translate from sketch to model is to identify the best mathematical relations or geometrical figure. Once this knowledge is secured, this type of tool can help the architect "catch the curve" or "create the curve", as indicated by Ceccato (2010). "To catch the curve" means to rationalize a solution that is conceived by traditional media, such as hand-drawing. To "create the curve" means that the computer can deal with levels of complexity and amounts of information that are not possible for human reasoning. The architectural approach described in this paper aimed to both "catch the curve" and "create the curve" and was implemented with Grasshopper.

1.3 *The programming interface*

In this sub-section we will describe the programming interface used to develop the parametric modelling solution. Grasshopper, being a visual programming tool, does not require the user to have high skills of programming or scripting. It works in a more intuitive basis and is particularly suited for designers who want to program generative solutions. Instead of writing text to describe the operations that the computer should perform, the user selects and concatenates specific objects using wires to describe the desired algorithm. There are two basic types of objects: parameters and components. Parameters store data and components perform operations. Components are divided in three parts: i) input parameters, ii) the component function itself, and iii) output parameters. Parameters are of two types: one type that inherits data from other components; and another type that does not inherit data, transmitting the data it stores to following components. The Grasshopper objects are grouped in categories (parameters, mathematical functions, sets, vector, curve, surface, mesh, intersection, transform). In each category we find sub-groups of objects. For example in the Maths category we can find: i) domain, ii) matrix, iii) operators, iv) polynomials, v) script, vi) trigonometry, and vii) utilities. One important notion is that data is stored as lists in a tree structure. A tree can have several branches and a proper path must be declared to access specific data in a tree [5].

The fact that Grasshopper runs with Rhinoceros makes it possible to set parameter values by picking data in a Rhinoceros drawing, although this is not strictly necessary.

In figure 1, on top we can see the typical layout of a simple Grasshopper program used to draw a parametric arch, and in the bottom we can see different versions of the arch, by changing the values of the input parameters, drawn in the Rhinoceros environment.

Intentionally, in the program structure all wires connecting different objects were left visible; nonetheless, as complexity of the program increases, a wireless display is also possible. Similarly, the objects can be set as visible or invisible. As the program becomes more complex, it is advisable to set intermediate objects invisible and set as visible only the objects corresponding to the solutions. It is good practice to place abundant comments in the program, as it facilitates debugging and makes the understanding of the program easier.

Another useful feature of Grasshopper is the ability to group sets of components, assigning customized

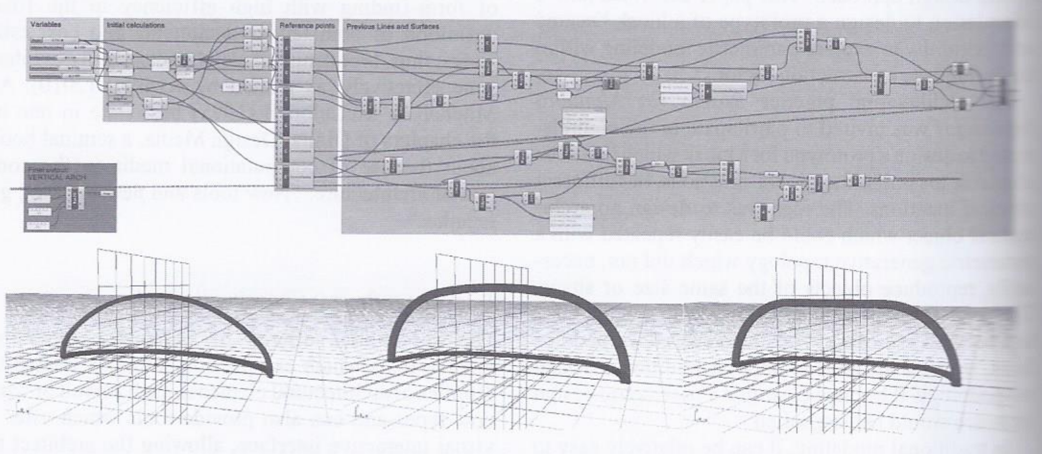

Figure 1. Top: Typical layout of a Grasshopper program. Bottom: Different versions of the output according to different values assigned to the parameters.

colours to the groups. This contributes to make the visualization of the program easier.

Although traditional programming or scripting skills are not required to program with Grasshopper, it is strongly advised to have a solid mathematical and geometrical basis.

2 DESIGNING A PROTOTYPE FOR A KIOSK

2.1 *Choosing the material and the fabrication technology*

The original concept was to design a kiosk entirely with renewable materials. The chosen materials were: LSF, light steel frame, technology for the structural elements; metal sheets for the roofing and exterior walls finishes; and Portuguese cork for the interior finishes. The metal sheets provided both finish and waterproofing for the exterior surfaces and the cork provided both finish and thermal insulation for the interior; thus, reducing the number of wall components. The choice of cork for the inside of the kiosk brought about the desire to intensify the spatial uniqueness of the kiosk, using the cork blocks as a dome like structure. The choice of the cork as the main material led to choosing milling as the fabrication technology.

2.2 *"Catching the curves"*

The definition of the inner surfaces of the kiosk was constrained by several conditions. Firstly, the outer boundary conditions of the kiosk had to be considered (Fig. 2). Secondly, the architectural expression intended for the surfaces led to the definition of some controls do adjust the shape of the surfaces.

In the final solution, the outer boundary is defined by: i) a frontal porch and back porch placed in parallel plans and both adjustable in height and length, ii) the distance (Depth) between frontal porch and back porch, and iii) the relative lateral deviation (Lateral Deviation) between frontal porch and back porch. Together these elements define two vertical plans in the sides and one oblique plan on top of the kiosk.

Inside of the space confined by those plans, were placed two main nurbs surfaces of degree 2. In the final model, the user can change the visual expression of the surfaces by changing the weights of the controls points of the supporting lattice. In fact, the user changes two extreme values and a function calculates the weights for the remaining control points. In figure 3 we can observe the effect of decreasing the weight of the middle points of the left surface.

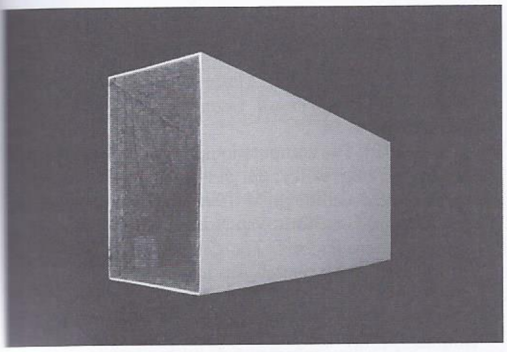

Figure 2. Physical Model: outer plans confining the inner surfaces. The cork model was fabricated in ISCTE's FabLab.

Left and right surfaces have independent controls. This way the user (the architect) can vary both surfaces in different ways trying to achieve the desired spatial qualities.

2.3 *Finding the stereotomic pattern*

Next modelling step consisted in dividing the visible surfaces with a wanted pattern (Fig. 3). In the final model, that pattern consists in the visible part of the final pieces that will be paced together. This defines a stereotomic pattern. This pattern takes into account the fabrication process, milling.

Initially, the surfaces were divided according to a visual criterion, as it can be seen in figure 4. The subdivision resulted from parallel plans with the same orientation as the frontal porch, defining arches, and from the projection of straight lines joining points from the frontal porch with points from the back porch, defining strips.

The definition of the volumes of the pieces took into consideration several facts: the milling distances that should be minimized, the adjacency of the pieces that is better solved if it is flat, and the maximum size of the cork blocks from which the pieces should be fabricated (100 cm × 50 cm × 10 cm).

Several possible solutions for the assembly of the pieces were studied and a colour code was added as an alert. Red, green and blue mean that length, width and milling distance, respectively, exceed specified thresholds. To overcome this issue the user had to assign different values to one or more parameters. By changing the parametric values, all pieces must lie within the specified thresholds and, therefore, correspond to a valid solution.

2.4 *Laying out the pieces for fabrication*

After the desired solution is obtained, the pieces are laid out for fabrication. At this step, it is important that all pieces are labelled, otherwise it would be impossible to know where in space a piece belongs. One possibility was to print numbers on the surface of the pieces which will remain hidden to the kiosk's users; however, the current idea is to use a text which will be printed in the visible surface of the cork, providing both a code for the builders and a poem for the kiosk's users.

As this is on-going work, the next step has not yet been implemented. The purpose is to optimize the placement of the pieces within the dimensions of the cork blocks and simplify the task for the builder who has to solve a puzzle where all pieces are different.

The desired result for the final pieces is somewhat what is shown in figure 5. The configuration displayed in figure 5 was obtained manually for a limited number

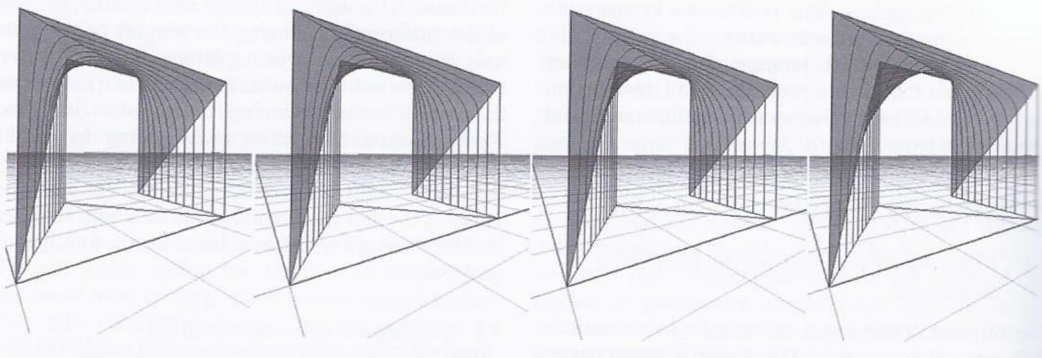

Figure 3. The effect of decreasing the weight of the control points (left surface).

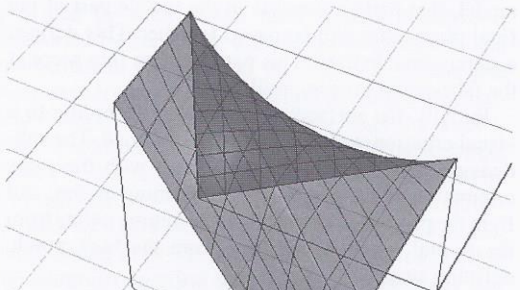

Figure 4. Stereotomic pattern.

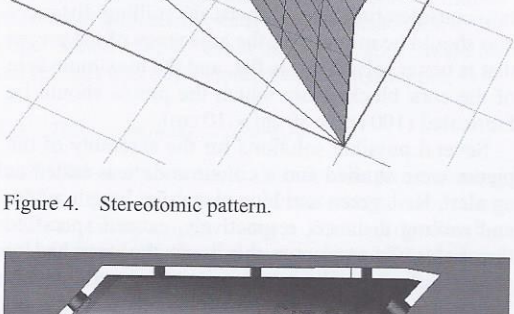

Figure 5. Manual optimization of the placement of the pieces in the cork blocks.

of pieces; however, this approach is not feasible for all the cork pieces.

3 CONCLUSIONS

The project presented in this paper aims to show how visual programming can be used as an effective tool for architectural design in ways that traditional media cannot be used. As indicated by Schumacker (2010), this represents a paradigm shift in the field of architecture, meaning new possibilities for the architect, further requiring new skills, without the demand to master traditional programming languages or scripting; however, traditional knowledge from the fields of geometry and mathematics is still fundamental. In this parametric design approach to architecture, a rationalizing attitude is needed, since it is important to understand that some design tasks can be thought of as algorithms. This approach does not bring about less creativity, but, on the contrary, welcomes computational tools as one more path to expand our ability to conceive architectural designs. With parametricism, the idea of single solution has to be replaced by the idea of a family of solutions embedded in the parametric system. This means that the ability to change the values assigned to the parameters enables automatically updating a solution or generate a complete new one.

The parametric design approach was able to solve all four challenges raised during the design of a prototype for a kiosk (the use of cork blocks, the curved surfaces, the stereotomy and the definition of the smaller components). In the design stage, all the challenges were solved with parametric modelling, using Grasshopper. The current problems this work faces are related to the construction process. The complexity of the construction process increased by threefold the cost of the cork because fitting together the cork blocks is still too complicated.

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