VPL as Design Learning Tool Between Geometry and Fabrication

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VPL as Design Learning Tool Between Geometry and Fabrication

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Abstract
Report of a teaching experience conducted in the 1st year of the degree course in architecture. VPL tools provide an educational interface to manage spatial geometric and architectural concepts. After being analyzed in the digital environment, each theoretical concept has its implication in an experience with digital fabrication tools.

Keywords Bachelor in architecture · Geometry · Visual programming language · Digital model · Rapid prototyping

Introduction

This paper displays an education project that involves knowledge of Visual Programming Language, digital representation and fast prototyping techniques for the understanding and representation of complex architectural geometries. The project is framed within the course of "Morphology", as part of the first year of the Bachelor Degree in Architecture at the University of Monterrey and it took place during the Fall Semester of 2022. While in architecture schools curriculum, particularly in those American school based on the Beaux Art education model, there still exist a net distinction between preparatory disciplines and problem-oriented integrated discipline (Maor and Verner 2007), or in other words between theoretical or technical disciplinary courses and design studios (Pugnale and Parigi 2012), this pedagogical experiments aims to mix different learning techniques, by using digital parametric tools (on VPL basis) as a way of establishing more

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fluid relationships between mathematical/geometrical aspects of architecture and fabrication/construction techniques.

The Research

The research displayed in this paper is a critical reflection on the competences and learning objectives of a pedagogical experiment in which students are subject to understanding formal aspects of architecture through an interdisciplinary approach that focuses on VPL as a learning tool. A qualitative systematic observation has been carried out during all 16 weeks of course development, through which specific competencies and learning objectives have been monitored and evaluated in the short and long run. The course of "Morphology" is a second-semester theoretical class in the first year of architectural degree studies. Students come to this class with no preliminary skills in CAD, having taken in the first semester the classes of composition, analytical drawing, descriptive geometry and an introductory course to architecture. Morphology is not a studio of architectural design, rather a supplementary course to support the design thinking for the entire study career to come, before students take the very first design studio in the third semester. Morphology covers a wide range of theoretical topics from digital modeling to programmed geometries, concentrating on everything that covers basics in geometries of the 3D modeling, various types of surface modeling, designing simple components and their possible aggregations, understanding topologies, parametricism and programmed fabrication (Riekstins 2018).

The first year of the bachelor degree in architecture is a fundamental background for students' future. In this framework, our project aims to provide students with a specific language and a critical overview for activating a vertical common distribution of knowledge over the entire degree's curriculum (Pavignano et al. 2022). Proposed activities are supported by theoretical lectures and moments of applied research to help students understand complex geometric shapes and their use within the architectural realm. In addition, several interventions by external professors have been scheduled to ensure an all-encompassing view of the proposed courses. By involvement in solving mathematical problems related to architecture forms and construction, and in geometrical design projects, the students gradually build their mathematical knowledge and develop the ability to use it in architecture design. To reach these objectives, the course offers an introduction to digital modeling, VPL language and digital fabrication techniques. The selected software for the development of the didactic activities is Rhinoceros 3D 7.0. The software is characterized by an intuitive interface, through which students can rapidly learn the basic functionalities. Rhino also enables students to go back and forth from the construction of a 3d model of complex surface to their analysis and representation in bidimensional projections, UE, or USA based on the selected standard (Bertoline et al. 2011). The Rhino's plug-in Grasshopper was introduced from the earliest weeks of the course. Through this particular VPL application, students learn on how to define the atomic steps through which to represent complex architecture and geometries in a digital format. Graphical elements, such as blocks and icons, which includes several programming languages and concepts, are typically used for educational purposes since they permit students to concentrate on basic programming principles without being overcome by technical difficulties.

The course was divided in different phases, each alternating theoretical lectures, practical workshops and exercises developed by students in class and at home. Following the initial lecture by the teacher, introducing a specific geometrical problem, the students' work was distributed in three separated weeks the first related to the understanding of specific geometrical problems, selection of architectural references and development of the design idea, the second related to the development of the algorithm in Grasshopper and 3d modeling, and the third related to the fabrication of the physical model. Each proposed session focused on one geometrical type classified according to CAD construction methods. The taxonomy adopted does not intend to be exhaustive in its selection nor comprehensive in its analysis, yet it aims to offer a key to understanding the geometrical problems of architecture as related to different digital modeling and fabrication techniques (Fig. 1). In this sense, the course aims to overcome the common geometry literature for architectural studies, based on elementary material or classical descriptive geometry. Instead, the course focuses on efficient CAD construction methods and uses CAD to support geometry teaching and understanding (Helmut et al. 2007).

Initially, the course focuses on developable surfaces, thus planar, rotational, and ruled surfaces, which thanks to their property to be unrolled on a plane, can be easily fabricated using paper or cardboard sheets. Students thus experiment with the fabrication of simple objects of which they can control mathematical properties (planarity and curvature) in VPL environments and thus cunting on precise and clear textual information. Subsequently, students move forward on developing and designing free-form NURBS surfaces characterized by a double curvature. Since these surfaces can not be unrolled, students experiment with their fabrication with rapid prototype techniques (3d printing), sectioning, and waffle structures. Here both rhino e grasshopper help students not only in the construction of complex digital models based on operations of extrusion, lofting, patterning and other parametric techniques, but also in the preparation of the model for the fabrication with actions such as contouring and nesting (Casale and Calvano 2011).

The course's last and more demanding part focused on the study of folding surfaces and related construction of physical models through laser cutting fabrication techniques. More in detail, starting from the study of the fold of a traditional origami model, this was translated into a digital environment through the coding of atomic modeling steps and their transposition into visual programming components using Grasshopper. The algorithms thus obtained describe the model's kinematics in all the folding phases. Parametric modeling allows students to specify the relationships between different parts of the model and code the geometry's behavior as the model is folded. This lets users easily view and understand the folding process (Fig. 2).

The representation of these forms through these Visual Programming methodologies are therefore not a mere copy of the object they are a procedure that generates knowledge concerning the analyzed object. Users are allowed to focus not only on the formal rendering of the modeling but on the modeling process, making it explicit (Calvano 2019). In the digital environment, the

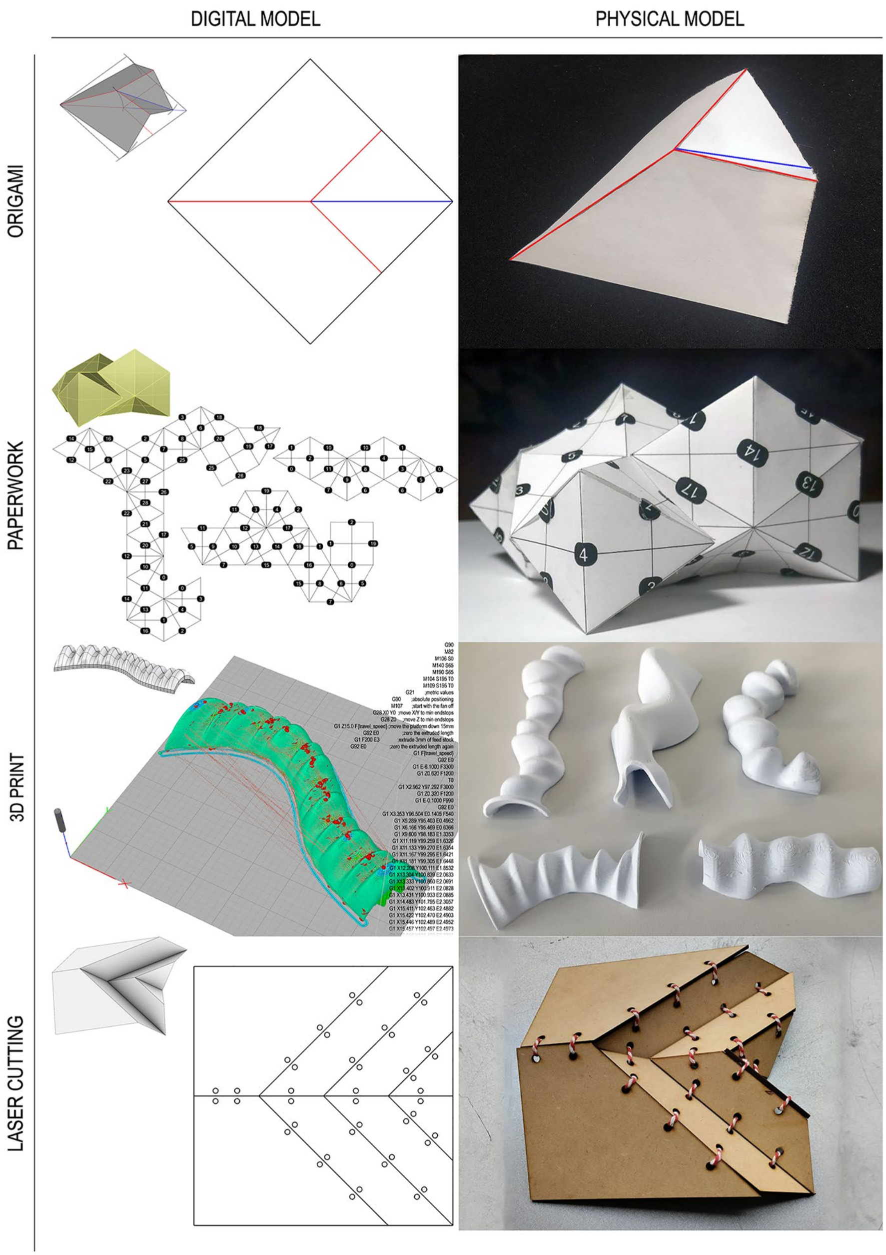

Fig. 1 The first table shows some of the geometric problems addressed. The examples are not exhaustive but offer various food for thought to students concerning the different digital modeling and manufacturing techniques

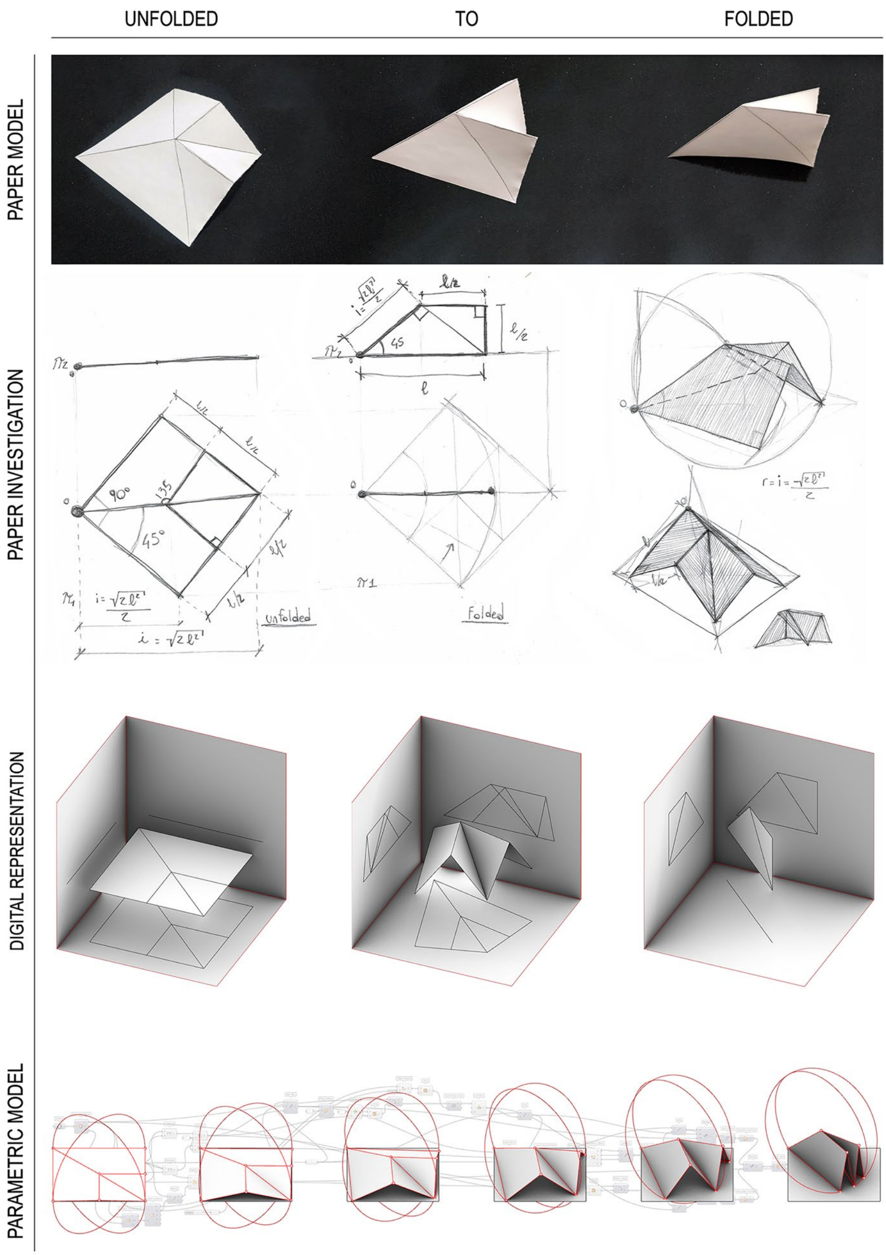

Fig. 2 The second table, produced with a collage of works by a group of students, shows the processes of analysis and representation of a specific origami figure in the distinct phases of the folding kinematics. It can be seen how with the introduction of the VPL methodologies, the representation becomes increasingly detailed, but how this has founded its foundations on the critical analysis which took place through a hand redrawing of the geometry

criticalities are then evaluated to move from materials of negligible thickness to prototyping with materials of non-negligible thickness. Indeed, the final part of the course involved students in a research activity in which they experimented with different materials and technical solutions for realizing semi-rigid joints. Students were then asked to move back and forth from the physical prototype to the digital model to test their solutions and make them available for fabrication. Each of the four parts of the course includes a study of mathematical concepts and methods connected to architecture, practice in solving geometric problems, and a design project involving both digital modeling and physical fabrication (Verner and Maor 2006). In this manner, students in the course learn to use mathematics as a source of creative solutions and as an instrument to answer design and fabrication criteria, such as constructive efficiency, optimization, shape variety, stability, and preciseness. Characteristics of learning in the course were then assessed based on a model drafted by Sarah Maor and Igor M. Verner (2007), which focuses on using mathematical concepts at each design phase, and related to the activities developed by the students during the coursework. Results of the assessment display in which phase and how the VPL language has worked to make mathematical concepts more evident and related to construction and/or architectural issues (Forsström and Kaufmann 2018).

Conclusion

The ex-post analysis of the proposed pedagogical activity underlines how using a specific language, calibrated according to the participants and supported by direct application experiences, led to a good response from the students. The association of traditional representation exercises with the coding of VPL algorithms has made some concepts that are not always easy to convey to students more “interactive" and “visible.” Conversely, good geometrical and mathematical knowledge has helped the learning process of these visual languages. The transposition of these concepts into physical models has further strengthened the skills intended to transmit to the students who, being able to "play" with the models, have acquired a greater awareness of the material and spatial properties of these architectures and geometries. Further pedagogical experiments, as well as their ex-post assessments, are required in the future to make the teaching of geometry and mathematics in architecture schools more effective at understanding digital tools applied to complex design activities and, thus more in line with the needs of changing professional reality.

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Data availability Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

Declarations

Conflict of Interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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