Didactic Experiences on Digital Modeling. Anamorphosis

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Abstract. This paper presents the didactic experiences on digital modeling developed in the last three years on Geometry and Architecture course of the 1st year of the Master in Architecture program of the Faculty of Architecture, University of Porto. For several years, this Geometry and Architecture course, was entirely concerned with projective geometry, and its most common representational systems used in architecture. However, since 2015, we decided to update its syllabus with the introduction of 3D modeling within the use of Rhinoceros software. The approach to the topic of three-dimensional modeling was made through the accomplishment of a teamwork in which the students explore Computer Assisted Design (CAD) processes in the study and resolution of geometry themes with impact on architectural design. With that goal, a three-year plan was defined and structured in the exploration of three topics: Anamorphosis, Tessellations and Surfaces. To demonstrate this didactic strategy and methodology, it is described in greater detail the experience dedicated to the Anamorphosis theme. As conclusion, the full paper acknowledges the success of these didactic experiences on the students engagement with the challenges, the potential of digital tools to support design development and the opportunity opened by the digital modeling on geometry teaching.

Keywords: Geometry · Digital modeling · Anamorphosis

1 Introduction

The first year of studies at the Faculty of Architecture, University of Porto (FAUP), comprises the following courses: Project 1 (21 ECTS), Drawing 1 (12 ECTS), Introduction to the Theory of the Space (9 ECTS), History of Ancient and Medieval Architecture (9 ECTS), and Geometry and Architecture (9 ECTS).

This Geometry and Architecture course, for several years, was entirely concerned with projective geometry, and its most common representational systems used in architecture, like cartography, topography, orthographic projections, axonometry and perspective. However, since 2015, we updated its syllabus with the introduction of 3D modeling within the use of Rhinoceros software, and we intend in the future to divide the year in two semesters: the first dedicated to perspective and hand drawing; the second dedicated to the 3D modeling of geometrical structures.

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It is relevant to mention that in FAUP master degree in architecture digital design as a support tool for the development of the architectural design is only introduced in the 3rd year. Recognizing the limitations of this methodological option and, above all, its divergence regarding contemporary reality, specifically in what concerns the architectural practice in which there's a strong interconnection with the digital world, we decided in the academic year 2015–2016 to introduce the use of the computer in geometry teaching.

Besides allowing to address a broader range of geometric themes, whose treatment through traditional representational systems is difficult to execute, 3D modeling leads geometry to become the core of the student inquiry. When the student creates a virtual model, his attention lies more in the objects geometry than in the representational systems, since the computer automatically provides this representation, increasing in a significant way the visualization ability and the spatial reasoning of the student.

In this paper we will present the experiences related to digital modeling that we promoted in the last three years, on anamorphosis, tesselations, and surfaces, focusing especially in the first one.

2 Didactic Strategy

Since the academic year of 2015–2016, the approach to the topic of three-dimensional modeling was made through the accomplishment of a team work in which the students explored Computer Assisted Design (CAD) processes in the study and resolution of geometry themes with impact on architectural design. With that goal, a three-year plan was defined and structured in the exploration of three topics: Anamorphosis, Tessellations and Surfaces. Being one of the most relevant CAD programs at the international level for architectural practice, Rhinoceros was the chosen software due to its versatility and easiness to develop three-dimensional geometric modeling operations.

The first theme—Anamorphosis (2015–16 year)—was understood as an extension of the last subject covered in the Geometry and Architecture course regarding the traditional representation systems. The subject of the anamorphosis allowed expanding, in a digital environment, the knowledge and skills of the students in the scope of linear perspective. The ground floor of the building of the Faculty of Architecture was presented to the students as a real context for designing and implementing the design of an anamorphosis projection using digital tools. Based on a previous survey, students modeled, simulated and tested the anamorphosis project. They investigated figures that could interact with space by "transforming it" and "questioning it" through disconcerting optic illusions. The final result was the production of a poster accompanied by a short video. One of the works was also selected for real on-site installation (see Fig. 1).

The second theme—Tessellations (2016–17 year)—considered solid tessellations, which take care of filling the space by aggregating polyhedrons with regular faces. This topic was studied through the creation of a spatial structure to be installed in Quinta da Póvoa Garden, one of the exterior spaces of the Faculty of Architecture building. Starting from an initial base module of regular and semi-irregular polyhedra, each group had to explore its possibilities of aggregation following the rules present in the base module. Progressively, they were expected to move away from the abstracting

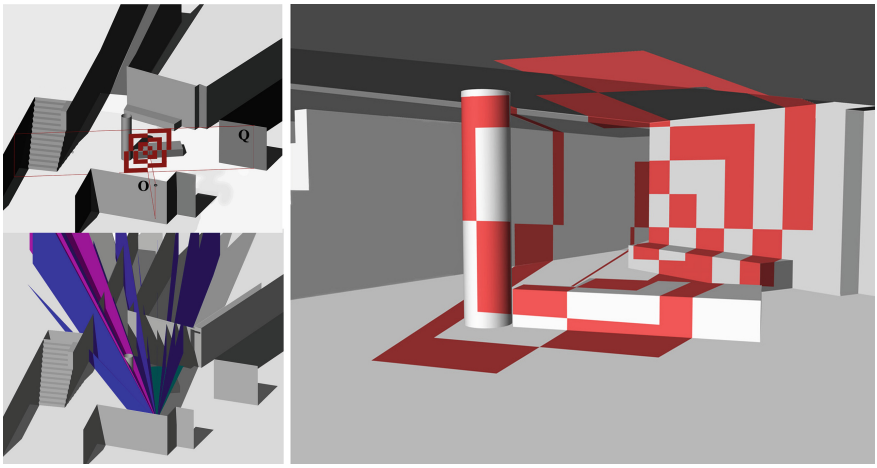

Fig. 1. 3D images of the anamorphosis work process and final result ("Geometric Atrium", work by Ana Lacerda, Maria Inês Alves, Maria Trindade and Ricardo Monteiro)

nature of these geometrical structures in order to define an inhabitable space built in the context of the garden. In addition to the virtual model, the students were asked to communicate the project through the production of a poster complemented by a physical model or, alternatively, a short video (see Fig. 2).

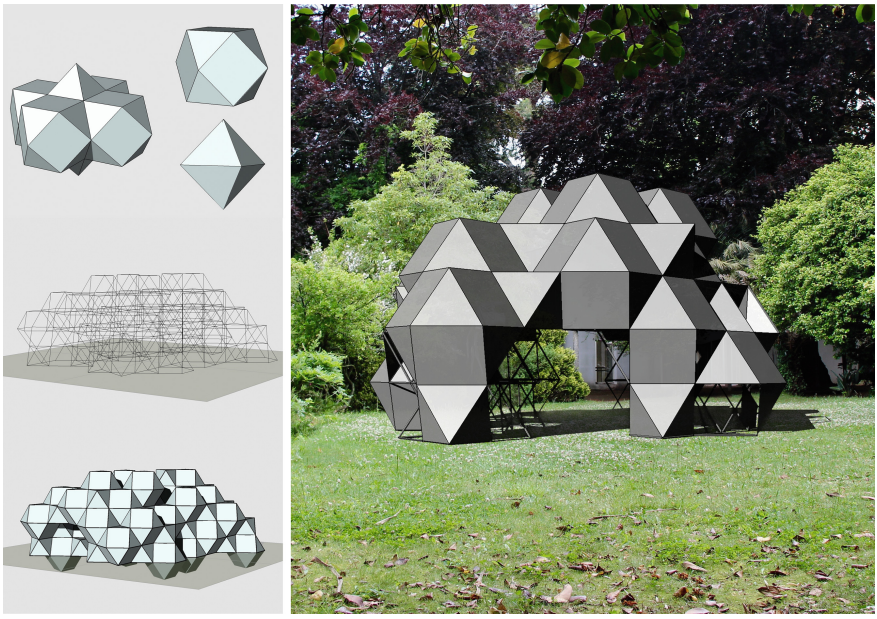

Fig. 2. 3D images of the tesselations work process and final result ("(In)tangible", work by Carolina Correia, Cynthia Machado, Nuno Delgado and Pedro Gouveia)

Finally, the third theme—Surfaces (2017–18 year)—was confined to a limited set of five ruled surfaces whose correct construction requires the careful recognition and control of the geometrical elements that structure its shape (i.e. generatrix and directrix). The proposed assignment challenged the students to design a project of a spatial structure exploring ruled surface geometries, and to be installed in the Botanical Garden of the city of Porto, in the area surrounding the main building—the Andresen house. From the surfaces presented in the class, each group selected one and had to use it as the base entity for the work. The development of the project explored strategies of creation, edition and transformation from the initially selected ruled surface. As a result of the work, the students had to produce a poster and to make a physical model or, alternatively, a documenting video.

The development of these three themes occurred under similar conditions. The time defined for each assignment was approximately 2 months, involving 6 classes with an average of 24 students each. The work development followed a common methodology based on the following phases:

- Presentation of the theme and theoretical framework;
- Software introduction and demonstration of relevant commands;
- Understanding of the geometry through early modeling experiments;
- Project design and development;
- Communication of the project.

To demonstrate this didactic strategy and methodology, which seeks to expand the teaching of geometry through the use of digital tools, we will describe and illustrate next the experience dedicated to the Anamorphosis theme.

3 Anamorphosis

Anamorphosis, according to its etymology, is a formless form.[1] But, in fact, its deformed appearance dissolves and the form, intentionally concealed, is revealed when viewed from a specific point of view. This condition of resurgence from a Point of View necessarily frames anamorphosis within the perspective, a projection system that can simulate the vision in a convincing way, especially when it is artificially reduced to monocular. This condition prevents the observer from having a perfect reading of the spatial depth inherent to binocular vision, and thus it is possible to manipulate the distances of objects regarding the Observer by bringing elements from the background to the foreground and/or vice versa, or even to combine different planes without the observer failing to see (or reconstitute) a coherent image formed onto a single plane that can and should be associated to the Projection Plane of perspective.

As for the accelerated perspective or delayed perspective, the prevalence of a coherent image regarding another that is not, will always be the one that our perceptive system will prefer, since it is inherent to it the option for the simpler, regular and more logical forms, in the sense of more expected [1].

[1] "Ana" is a Latin or Greek prefix with a sense of "up", "again", "opposite"; "morphe" (morphe), is a Greek element of word composition that expresses the idea of "form".

The anamorphoses are classified in different types, established according to the shape of the surface or surfaces on which the image is projected [2]. These types, enumerated according to their emergence, are as follows:

- oblique anamorphosis—the image is projected to an oblique plane, strongly skewed in relation to the Projection Plane;
- anamorphosis by projection on differentiated surfaces - these surfaces can be pyramids, cones, cylinders, spheres, etc.;
- catoptric anamorphosis (cylindrical, conical, pyramidal, spherical, …)—the image is generally projected onto a plane, although is mediated by the interposition of a cylindrical, conical, pyramidal, spherical or other mirror;
- anamorphosis by spatial deconstruction—in this case, the image is fragmented in several planes and/or three-dimensional elements, disseminated in space. Viewed from the projection center, an image corresponding to a uniform space or object (bi- or three-dimensional) is clearly identifiable.

It belongs to this last family the challenge proposed to the 1st year students of the Master Degree in Architecture of the Faculty of Architecture, University of Porto, (FAUP) in the academic year of 2015–2016, within the scope of the course Geometry and Architecture.

Being, historically, the most recent type of anamorphosis, initially related to landscapes and gardens interventions (from which the well-known *anthropomorphous campus* of Athanasius Kircher (1646) is a greater example) it is also the one that most enhances a spatial intervention since it provides a great interaction between the image and the chosen place for the anamorphosis. And if it is true that the anamorphosis influences the reading of space, transforming the perceptive experience of those who go through it, its knowledge and instrumentalization prove to be of a great interest to those who, as a student and later as a professional, will have space as raw material for its design activity.

3.1 Methodology

Over 5 weekly lessons, about 160 students of Geometry and Architecture, organized in groups of 4 or 5 students, carried out the practical exercise dedicated to anamorphosis theme, which sought to articulate three main objectives:

- to understand the theory of anamorphosis and explore, in practice, its potential to influence spatial perception;
- to introduce the use of computers as a means to support conception, representation and communication of an anamorphosis;
- to build a real-scale installation (1:1), to demonstrate and experience the anamorphosis project.

With this purpose, the ground floor of the building of the Faculty of Architecture was presented to the students as a real context for designing and implementing the design of an anamorphosis. Delimited between the east door, that gives access to the corridor, and the bar entrance, the intervention area is characterized by a diverse set of spatial situations that offer several opportunities for the idealization of anamorphosis.

To carry out the anamorphosis design, it was used Rhinoceros software. Aiming a spatial intervention, this digital environment proves to be ideal for the modeling and simulation of the anamorphosis project.

After a theoretical introduction, in which works such as those of Felice Varini were presented and discussed, the development of the anamorphosis project in CAD environment was structured sequentially in the following phases:

Phase 1—Modeling of the existing space

Selection of the intervention area and modeling of the planes that define the space needed to the context and projection of the anamorphosis. For the three-dimensional modeling, the students proceeded from the plan through line extrusion processes and surface editing.

Phase 2—Definition of the basic elements of the anamorphosis

Modeling of the Point of View (projection center) and the Projection Plane (surface). Since the anamorphosis can be considered an inverse operation of perspective, the idealized Image (geometric composition) must be drawn directly on the Projection Plane (see Fig. 3).

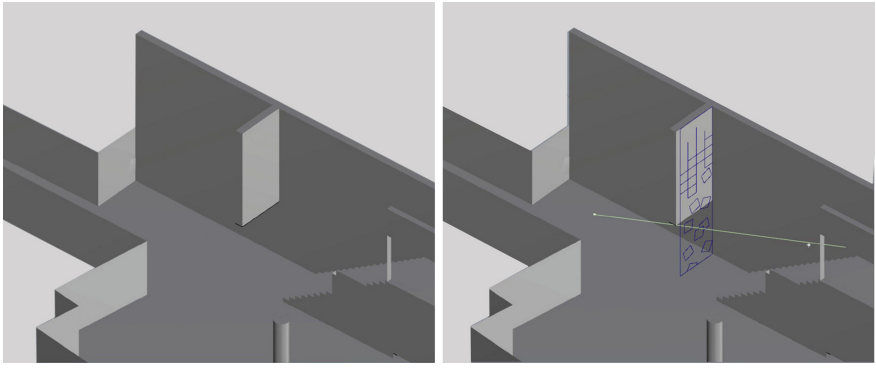

Fig. 3. Modeling of the intervention area and definition of the basic elements of the anamorphosis ("Tiles", work by César Silva, Cristiano Alves, Diogo Barbosa and João Naia)

Phase 3—Projection of the geometric composition onto the space surfaces

Determination of the implicit projection in the anamorphosis by the extrusion of the figure contour lines to the Point of View (projection center). The converging surfaces resulting from this projection were subsequently extended, in the opposite direction, till they intersect the planes that define the architectural space, obtaining in this way the figure fragmentation on the different surfaces (see Fig. 4).

Phase 4—Simulation and evaluation of the result

Evaluation of the anamorphosis figure construction/deconstruction through navigation in the model. This simulation allows to evaluate the effect of the anamorphosis and verify the need to redo the process changing the initial data. This use of the computer promotes an iterative process of trial and error that assists the project and its progressive refinement (see Fig. 5).

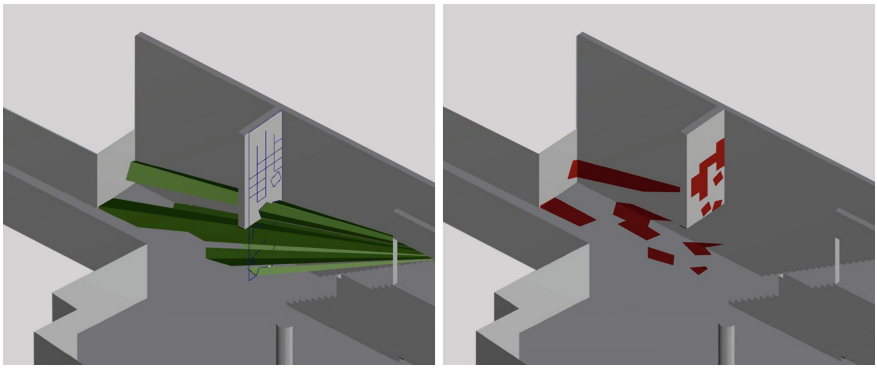

Fig. 4. Projection of the geometric figure and determination of its fragmentation ("Tiles", work by César Silva, Cristiano Alves, Diogo Barbosa and João Naia)

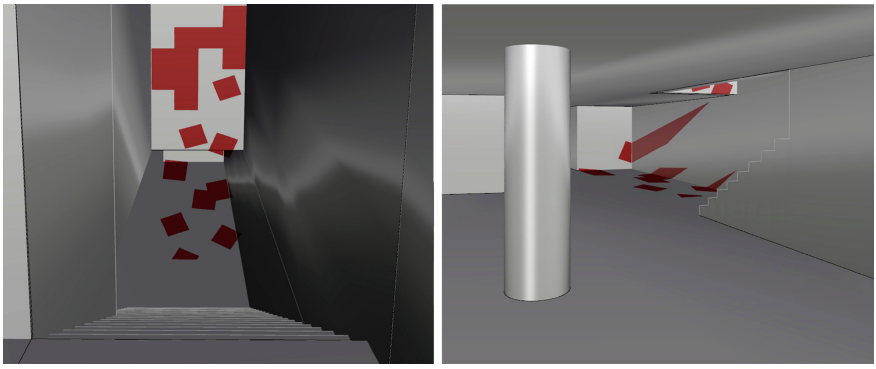

Fig. 5. Evaluation of anamorphosis project ("Tiles", work by César Silva, Cristiano Alves, Diogo Barbosa and João Naia)

Phase 5—Communication of the design project: poster and short movie

Communication of the project by production a poster and a short movie. Using a poster template provided on the exercise, the students inserted CAD-produced images documenting: the space model, the definition of the anamorphosis elements, the projection of the figure, its fragmentation on the space planes and the simulation of the final result, with the fragmented and reconstructed figure. Using a screen video capture application, they explored zoom and pan movements to assemble a sequence starting from a point of view where the image appears fragmented and concluding with the Observer point of view where it appears integrally (see Fig. 6).

3.2 Results

The accomplishment of this work resulted in the production of 32 anamorphosis projects for a delimited area of the FAUP building. There is in most of them a desire to create an image that provokes space, that interacts and dialogues with it, either by the

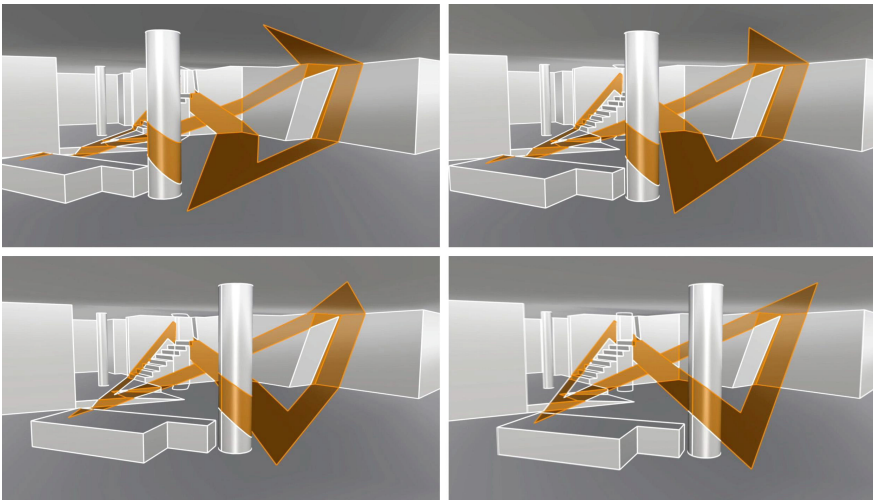

Fig. 6. Set of frames extracted from one of the animations produced (work by Cláudia Araújo, Leandro González, Patrícia Resende and Sebastião Rebolo)

creation of virtual architectural elements, or by the fictitious lengthening or shortening of space, or even by the creation of figures and objects that question space through the creation of bewildering optical illusions.

In a retrospective analysis of the presented proposals, it is possible to distinguish among the different groups the adoption of similar creative strategies, such as:

- geometric composition that is indifferent to the architectural features of the existing space (see Fig. 7);
- geometric composition that establishes relations with the existing space by taking advantage of its architectural features (see Fig. 8);
- geometric composition that introduces new architectural elements in the existing space (see Fig. 9).

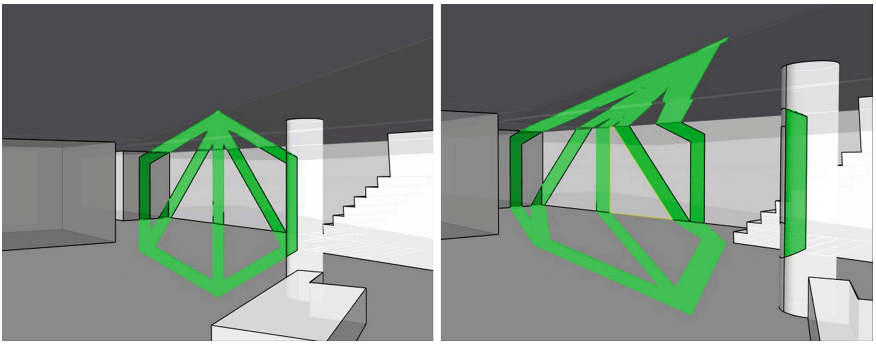

Fig. 7. "Porto Academy'16", work by Ana Sofia Alvim, Catarina Casanova, Davide Fernandes and Jorge Ribeiro

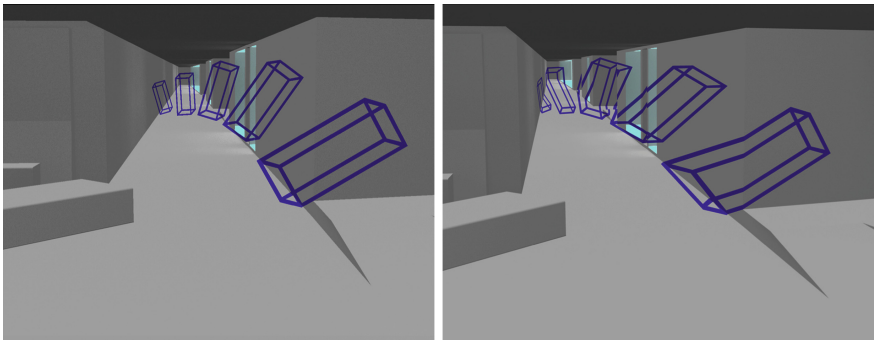

Fig. 8. "The Fall of the Polyhedron", work by Ana Carvalho, Beatriz Falcão, Carolina Queirós and Fábio Fonseca

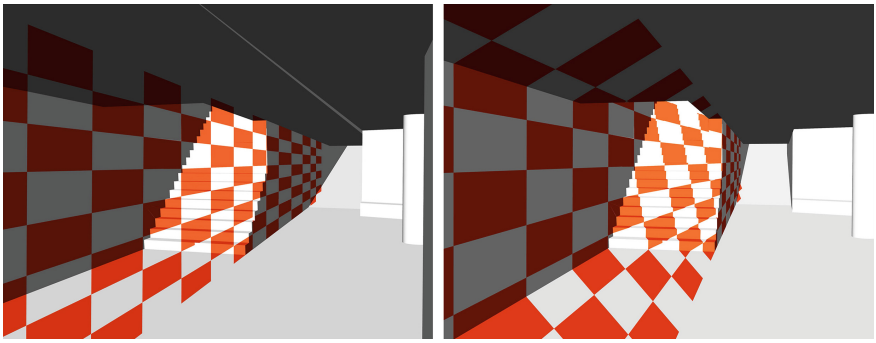

Fig. 9. "(In)visible Wall", work by João Magalhães, Natacha Sá, Rodrigo Alves and Rodrigo Amaro

3.3 Implementation

As conclusion of the exercise, it was selected one of the projects presented by the students to be installed at 1:1 scale in the corresponding space of FAUP.

The work chosen to be carried out under the Anuaria' 16 exhibition is entitled "Around the column", it was developed by the students Carolina Videira, Inês Costa, Inês Santos and Siana Kostova and it is part of the type 2, "geometric composition that establishes relations with the surrounding space, taking advantage of its architectural features", as mentioned in the previous point (see Fig. 10).

This anamorphosis takes place in the atrium of the ground floor of the faculty building, at the confluence of three ways, the corridor that leads to the bar, the ramp that goes to the auditorium and the access corridor to the towers. The image of the anamorphosis has as background the living space between two seats, arranged in a V-shape, and the column around which the various ways are articulated, reconstituting itself from the Point of View of who comes from the bar and sees the column aligned with the axis of the field of vision.

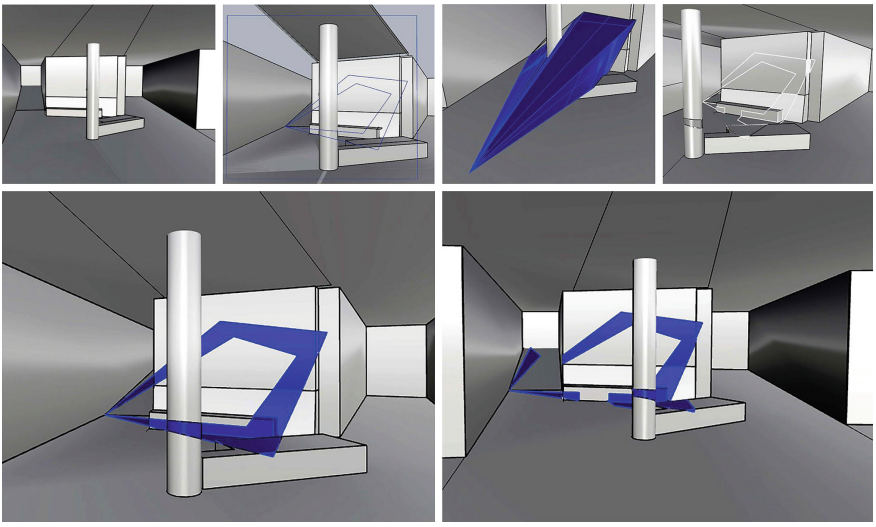

Fig. 10. Presentation images of the work "Around the column". Work by Carolina Videira, Inês Costa, Inês Santos and Siana Kostova

The image of the anamorphosis consists of two quadrilaterals with different dimensions, united by one of the vertices, that define between their contours a cobalt-blue geometric figure that is oblique regarding the Projection Plane.

Despite the strong reference to the work of Felice Varini, this project acquired its own autonomy by the way students developed the relation with the site, finding in this strong dialogue its distinctive and unique features.

The figure of the anamorphosis establishes relationships with the space in which is projected, involving the column that organizes this living area and touching with the common point of the two quadrilaterals in one of the vertices of the ramp that rises towards the auditorium.

The subtlety of relations that the figure establishes with the architectural elements was determinant in the selection of this work to be executed. On the other hand, compared to other proposals submitted by the students, this anamorphosis is contained regarding the extension of surface on which is projected, and, above all, is very effective regarding the Point of View from which the image is reconstructed. As mentioned, the figure of anamorphosis becomes perceptible from a point of great affluence (bifurcation of the way that comes from the bar), by which the school community circulates everyday in a natural way.

The installing process of the anamorphosis took place in four phases (1-projection of the figure in space with a video-projector; 2-delineation of the figure on the surfaces; 3-application of the vinyl; 4-identification of the place to observe the anamorphosis) and involved several students who readily became available to experience the project installation at 1:1 scale (see Figs. 11 and 12).

Fig. 11. Installation process of anamorphosis, figure delineation and application of vinyl sticker

Fig. 12. Anamorphosis construction/deconstruction

4 Conclusion

As conclusion, we may say that the result of the didactic experiences carried out over these three years has been extremely positive.

Students have embraced these challenges very well, revealing a strong empathy and ease in accepting digital drawing technologies, which is, in itself, a great stimulus to arouse interest and motivate them to work. Also for this reason we noticed, with a certain naturalness, that the methodology for generation, modeling and design development is assimilated in a clear way by the students and it is quickly put into practice.

From an operative point of view, the advantages of digital design, as a tool to support study and resolution of geometry themes with impact on architectural design, are very relevant. By allowing the immediate visualization of objects, three-dimensional modeling facilitates the understanding of their geometric structure, leading to a greater control of the elements that support it. At the same time, by facilitating the verification of results and the assessment of solutions, working in 3D environment expedites the design process and above all extends the possibilities of experimentation. Digital design proves in this way to be adequate to the study and development of geometry themes of some complexity, whose treatment by the traditional representational systems is difficult to execute.

Finally, regarding Geometry and Architecture course, digital modeling poses a stimulating challenge since it allows to open the program of the course to geometry topics so far less explored and at the same time very pertinent in the context of contemporary architectural practice.

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