Ana-Maria GRAUR, Georgiana CORSIUC

STUDENTS' APPROACHES ON THE GEOMETRIC TRANSFORMATIONS

Abstract: *Architects represent volumes on a bidimensional surface, by using geometrical rules so that later they can build the reality in three dimensions. Thus, Descriptive Geometry taught to the future architects must provide basic knowledge regarding the creation of space, forms and methods by which they can be represented. With the new space viewing methods in computerized era, which allows incontestably complex connections in an entirely new manner makes us ask the question "is geometrical thinking still necessary?" This work analyses the ways in which descriptive geometry, by geometrical transformations allows the students architects the realization of volumes and architectural spaces, especially the role it plays in the development of spatial thinking.*

Keywords: *education, geometric transformations, translation, rotation, roto-translation, architectural design.*

1. INTRODUCTION

Architecture, engineering and environment generate information and fundamental relations in the realization of built environment and geometrical knowledge plays an essential part in satisfaction of these conditions. The main mission of descriptive geometry, as subject in architectural education, is the development of tridimensional thinking, formation of a precise and logical spatial vision and implicitly the development of strategies of efficient solutions for various problems. The training of students in the first year of study implies a substantial effort in their task of designing the tridimensional space. At the beginning of studies, the assimilation of design steps is made by drawing and later by realization of models which offer a new means of analysis of form and representation concept.

2. OBJECTIVES OF GRAFICAL EDUCATION

In the first year of study the computer use in creation of architectural design is restricted, laying emphasis on the sense of proportion given by the drawing scale, sketching with free hand being the best way of developing the perception, and in the subject Descriptive Geometry, the drawing with free hand makes the learning process much more efficient. The start of this graphic research through descriptive geometry is crucial in the stages of completion of architectural drawing, therefore it certifies the necessity of a unit between geometric thinking and constructive thinking. The main objectives of architectural drawing are the viewing of space/volume and this skills is acquired by a very good capacity of perception. Abstract thinking of drawings represented in projections is the basis of day-to-day activity of architects. The objective is to provide tools for imagining and representation with precision and dexterity of expression of architectural tridimensional form, a repertory in continual change.

The main reason for the necessity of using the representations of descriptive geometry is the biunivocal correspondence between the finished product, architecture and drawing, which makes possible the checking of measurements and sizes. Such representations attest the whole system and the process which encapsulates the logic of projective geometry. On the other hand, this biunivocal relationship is determined by images and drawings which define the systems of lines, relations, sizes, exact positions in the land, surveying measurements, the position and form of structure/architecture, an assembly understood as projection at a certain scale, of reality, making everything possible by orthogonal projection.

2.1. How to communicate with students

By courses, works and workshop exercises the students can follow historical, theoretical fundaments and the technical bases of projective geometry which will offer the bases of development of a specific vocabulary. That is why, the theoretical courses take the shape of debates and the practical workshop mean effective construction of models and representation of technical drawings, the very confrontation with built reality. Students depend on these drawings in the development of projects, localize the problematic areas and their resolution. The drawing facilitates the thinking process and allows for interdisciplinary communication with all those involved in the constructive process of architecture [1]. The objective is not the quantity of information stored, but the creative potential and originality of architectural form from the perspective of determination of its structural, functional, aesthetic and cultural symbolic form.

2.2. Themes on design and graphics activities

Abstract thinking in descriptive geometry is a perfect environment for design in tridimensional space. The first-year students of the Faculty of Architecture and Urban Planning of Cluj-Napoca accomplish better this task by themes and tasks which are normally related to architecture. In order to accomplish this target we approached in the subject Architecture Design 1 a very interesting theme which proposes the realization of a temporary pavilion which will be located in the urban

space. The object proposed, of small sizes, with an area of 100m2, will have the destination of complementary space for cultural or entertainment events or will serve as support of the simple relaxation in the public space. This design theme correlated with geometric thinking will provide very interesting results and will maintain a high level of motivation, which is essential vor the success of developing imagination and tridimensional thinking. Because the theme does not impose a precise function of pavilion, in its conception we will have in view the possibility of its adjustment to various functional requirements it could fulfill.

3. APPLIED DESCRIPTIVE GEOMETRY. GEOMETRIC TRANSFORMATIONS

The notion of geometric transformation appeared from the consideration of movement notion in physical space, which keeps the form and size of figures at initial and final moment of the movement. Thus, from geometric point of view we are interested in the process of transformation of the figure we consider, the correspondence between the figure points at the initial and final moment and the properties of figure which remain unchanged after the transformation. We believe that a geometric transformation acts not only on a figure from plane or space, but on all the points of a plane or space [2].

Therefore, the transformation of flat figures means an operation by which we make correspond a given figure to another figure, by a certain rule, called transformation law. If each point from the first figure corresponds to a well-determined point from the second figure, we can say that there was a punctual transformation. The points which correspond in a punctual transformation are called homologue points. If F' is the figure obtained by transformation of figure F, then we say that F' is the transformata of figure F.

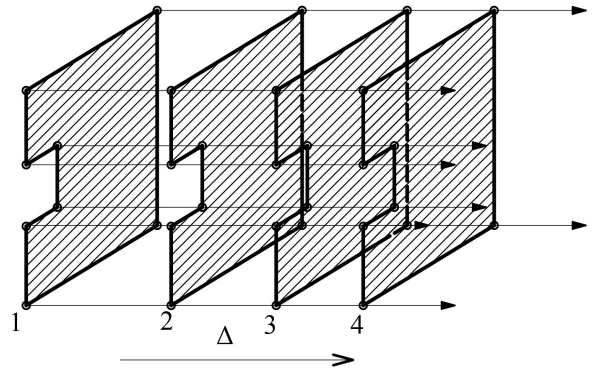

Fig. 1 Translating a polygon.

3.1. Translation transformation

Translation can be defined by the idea of movement or travelling, more exactly, as a transformation by which all points go in one and the same direction, in a given direction and at the same distance. Thus, the rectangle from Fig.1 is translated by parallel travelling, in direction Δ, of each point of rectangle. From the initial position 0, the rectangle was successively translated in positions 1,2 and 3. By translation, a flat figure can generate a solid body, if we retain all the intermediary positions of the figure in movement. In this case, the body generated by translation is a prism. If we translate a cube we can get a polyhedron irregular, Fig. 2.

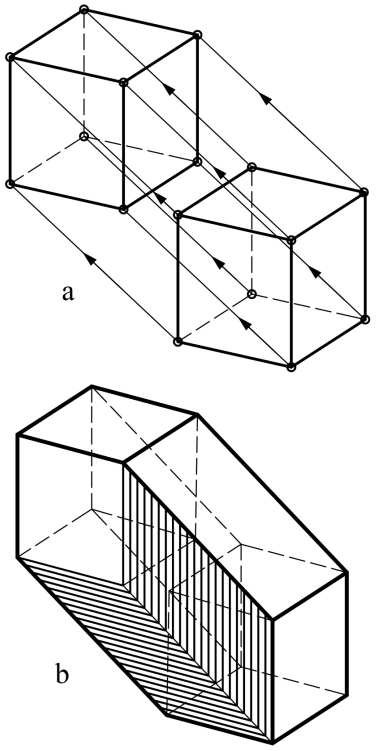

Fig. 2 Translating a cube.

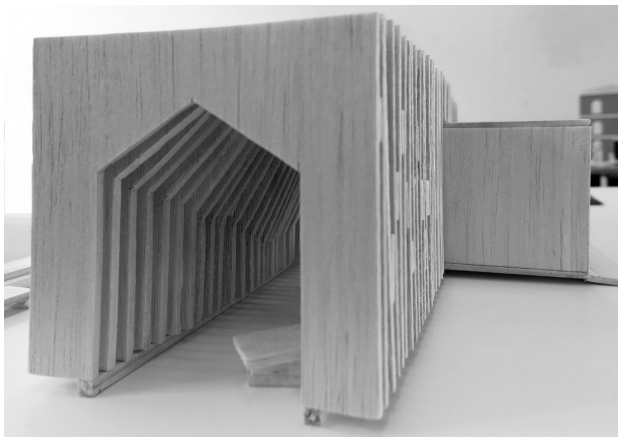

Fig. 3 Model made by student using translation transformation.

3.2 Answers given by students

We want to present below the use of geometric transformations and their implementation in models which surprise both the volume of architecture object and the indoor space, they were made by the first-year students of the Faculty of Architecture and Urban Planning. The model, the tridimensional model of concept drawings, offers a very good visual support,

being the most suitable communication pathway between the designer and beneficiary. According to the design theme of the first year – "Temporary Pavilion", students have a great liberty in choosing the architectural forms. Thus, some of them chose translation as a process of creation of space of architectural object, materialized by flat figures translated along an axis. In Fig. 3 the plane of translated square has a polygon missing, which suggests the image of a small house, resulting in a stratified space tunnel type. Fig. 4 presents a structural frame which travels along an imposed direction, which generates an animated external space. By application of translation a single inconvenience appears, the indoor space resulted is longitudinal, thus the students are forced to add other volumes in composition.

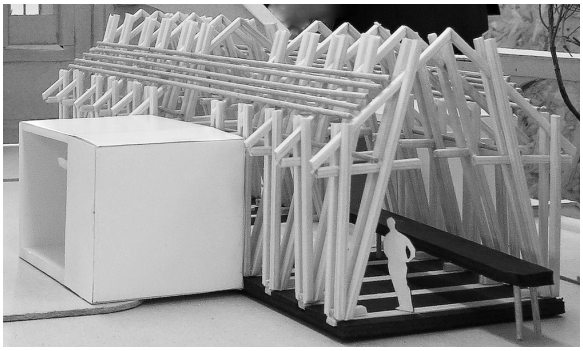

Fig. 4 Model made by student using translation transformation.

3.3 Rotation transformation

This is a transformation which rotates points in a given direction, around an axis called rotation axis by a fixed angle called rotation angle. Point B rotates around the rotation axis by a certain angle α, reaching the position B1. Point B1, just like all intermediary points, is located on a circle which is perpendicular to rotation axis and with the centre in ω, so that the measure of angle BωB1 is α [3]. The rotation of straight line AB, parallel with rotation axis, generates a cylindrical surface, Fig.5.

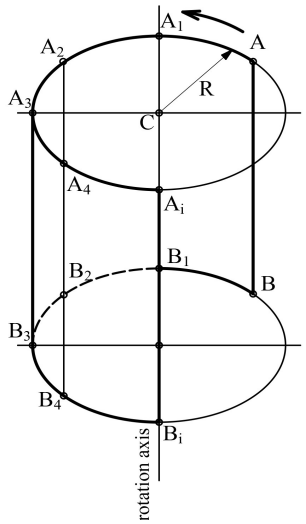

Fig. 5 Rotating a straight line.

3.4 Answers given by students

The use of primary forms, an example is the circle, as generator of architectural forms is one of the most encountered methods in design. Students can be attracted to circular or curvilinear forms, and the application of rotation as method of generation of a space can be one of the methods of obtaining it.

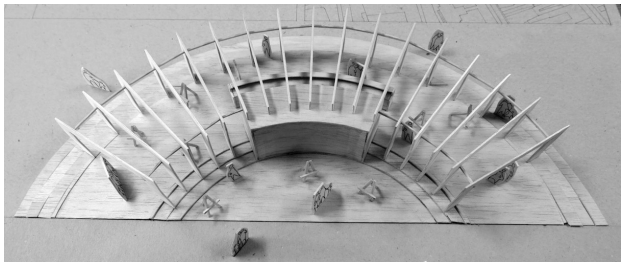

Fig. 6 Model made by student using rotation transformation.

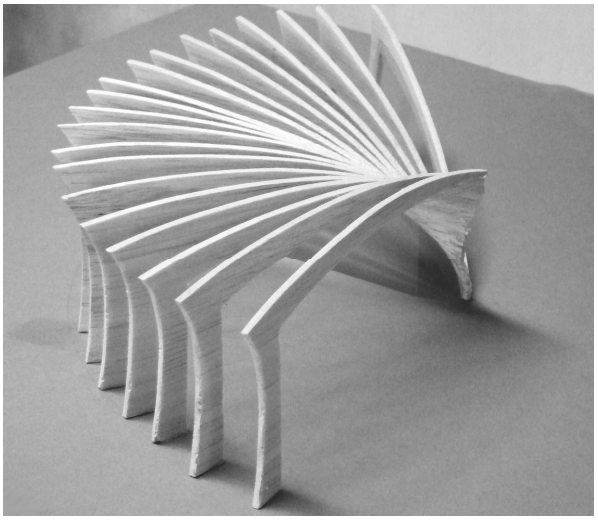

Fig. 7 Model made by student using rotation transformation.

In Fig. 6 and Fig. 7 students started from the rotation of a frame under a certain angle which generated the change of visual field in the inner route proposed. In Fig. 8 the circular space is closed, limited, but the rotation movement which defines it has an infinite potential, highlighted by the openings marked in polychrome. From inside, each frame door offers a new perspective on the external space.

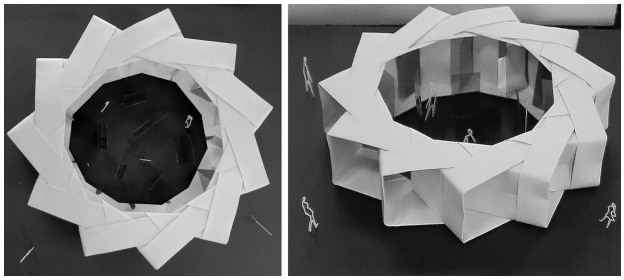

Fig. 8 Model made by student using rotation transformation.

3.5 Roto-translation transformation

The transformation by roto-translation is a combination of transformation by translation and transformation by rotation. Point A rotates around the rotation axis and simultaneously advances along this rotation axis, which means that the ratio between its axial travelling and its angular traveling must be constant. Each point in roto-translation describes a helix, Fig. 9, [4]. For a flat figure, this change of position is made by rotating all the points which define the geometric figure around a rotation axis in a certain direction. So it needs: a rotation axis, a rotation centre, a translation direction and we will take into account that the rotation axis is perpendicular to rotation plane.

A straight line located initially in a certain position towards the rotation axis will describe by roto-translation a curvilinear ruled surface.

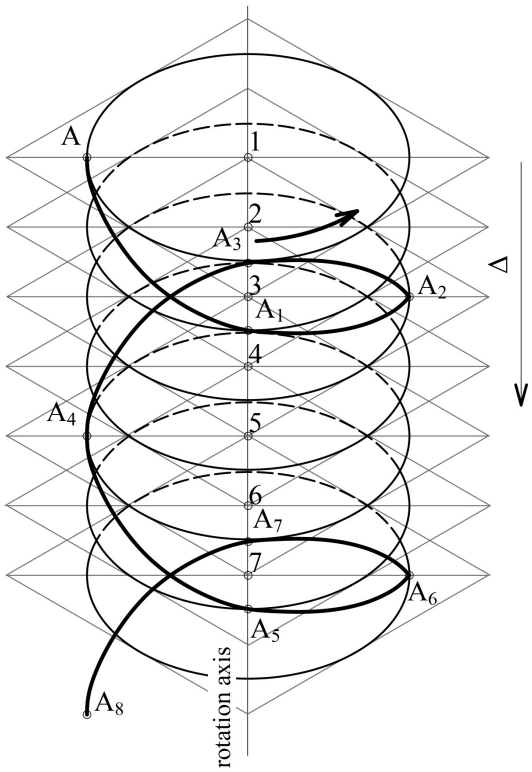

Fig. 9 Roto-translation transformation.

3.6 Answers given by students

By the movement given by roto-translation the plane of geometric figure changes position and rotates at the same time, the final result being a volume which gives the feeling of movement. In Fig. 10 we can see how the square plane generates along the translation route a stratified space defined by the structure itself, the square frame. In Fig. 11 the structural frame is half of a hexagon which is translated and rotated, generating the compartmentalization of the indoor space. Concepts are ideas which integrate various elements in a whole and become an important part of architectural design. We can thus notice the concepts proposed by students in these models and the way in which thinking and geometric knowledge made possible the materialization of architectural shapes.

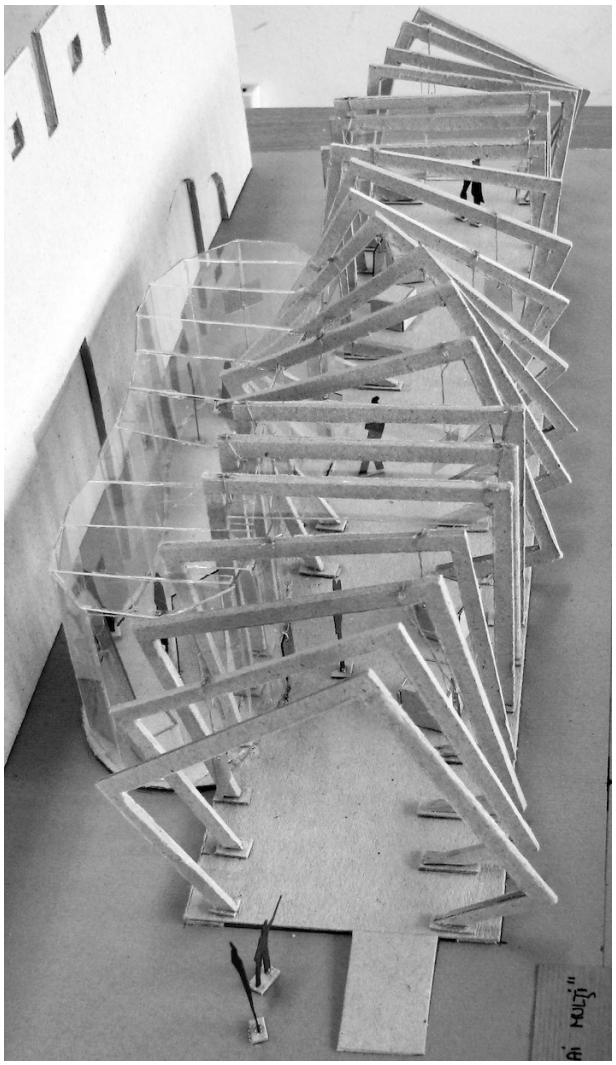

Fig. 10 Model made by student using rotation-translation.

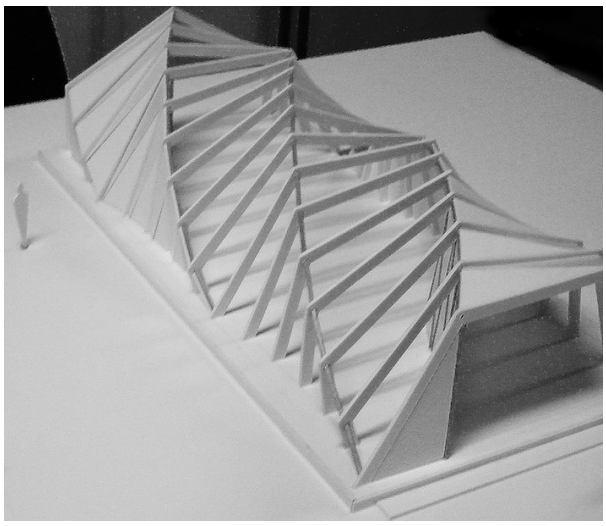

Fig. 11 Model made by student using rotation-translation.

4. INTEGRATION OF THEORY AND PRACTICE: EXAMPLE IN COURSE

Practical examples motivate the students to actively participate in the realization of models at small scale and makes them understand better the process. The application of geometric transformations in architecture and engineering involves the movement and they suddenly evolved at the end of twentieth century as a result of technological and scientific progress in mechanics, electronics and robotics. Kinetic architecture blends various techniques and styles which make this current be as varied and interesting as possible, and the movement capacity of a building can be used not only to promote its aesthetic qualities, but also to respond to environmental conditions, to fulfil various functions which would be impossible in case of a static structure.

4.1 Translation. Fields of use

An illustrative example would be the constructions from the category of kinetic, dynamic architecture, a concept by which they allow the structural part to move, without reducing the general structural integrity. Thus, the London architects dRMM conceived a house in Suffolk, England, whose walls and roof are mobile, allowing the coverage or uncovering of parts of the house, Fig. 12. It has a structure which glides along buried rails, over the main static body, over the annex for guests and hothouse. This mobile element is 28 metres long and weighs 50 tons [5]. The transformation by translation is valorized at maximum by offering completely different spaces, images and shapes.

The translation itself creates a change of position of the volume in space, while the direction remains the same, perpendicular to the short side of the house.

Fig. 12 Sliding house, dRMM architects [6].

4.2 Rotation. Fields of use

The following example is a residence, Sharifi-ha house, made by Nextoffice, architect Alireza Taghaboni, located in Teheran, Iran, which uses transformation by rotation applied in exceptional method, Fig. 13. All the composition of the project focuses on some modular wooden boxes which open and close according to the weather [7]. Three external terraces allow the wooden boxes to rotate and open in summer, and implicitly the extension of terrace space, while in cold winters, their closure and protection of the indoor space. The technology used by architects and engineers was similar to theatre stages. One of the problems the designers had to face was the correct estimation of structural loads and control of vibrations which could lead to structural deformities. The whole construction is deployed on seven floors with a logical distribution of various functions. As we can see the rotation movement implies the keeping of position around a single rotation axis and the movement of volume direction.

Fig. 13 Sharifi-ha house, architect Alireza Taghaboni [8].

4.3 Roto-translation. Fields of use

A much more complex image offers the combination between transformation by rotation and transformation by translation. The successive overlapping of transformation steps creates a stratified folded volume [9]. This is the case of the following example in which the architecture office MAD made Absolute Towers, two residential towers with 56 and 50 floors in Mississauga, Canada, Fig. 14. The torsion of twin towers is given by the fluidity by which the vertical lines are twisted in a natural manner. This rotation offers each resident a unique and personal experience by the terrace-balconies which open on the outside and widen the visual field.

As we can see the application of geometric transformations in constructions field marks a new beginning, a new era in architecture, a challenge for traditional architecture, which changes not only the appearance of the cities, but also the idea of modernity.

Fig. 14 Absolute Towers, MAD office [10].

5. CONCLUSIONS

For the purpose of engaging the critical capacity of students, it is necessary to blend the real/practical experiences with geometric analysis and with descriptive and constructive methods.

This procedure generates a greater independence in making decisions, an overview and adoption of the most suitable strategies for solving various design and structural problems.

The combination and manipulation of these geometric transformations over basic geometric figures by rotation, translation and combination of the two, roto-translation, can lead to generation of more complex architectural shapes.

Last but not least, translation and rotation generate movement and dynamic architecture is a more and more present reality today and an important step to the future in architecture. It is not only a new chapter in architectural aesthetics, but also plays a very important part in improvement of a building's functionality.

REFERENCES

[1] Marza C., Iacob G., *Representation methods from the curricular area of descriptive geometry, put in agreement with the law for quality assurance in higher education,* The International Scientific Conference for Geometry and Engineering Graphics "moNGeometrija2010", Belgrad, Serbia, editia a II-a. ISBN 978-86-7924-040-8

[2] Dumitru, S, Nicolae S., *Transformari geometrice (Geometric transformation),* Editura Academiei Republicii Socialiste Romania, Bucuresti, 1988.

[3] Enache, E., Ionescu, I., *Geometrie descriptiva si Perspectiva (Descriptive Geometry and Perspective)* Editura Didactica si Pedagogica, Bucuresti, 1983.

[4] Botez, M. *Geometrie descriptiva (Descriptive Geometry),* Editura Didactica si Pedagogica, Bucuresti, 1965.

[5] https://www.dezeen.com/2009/01/19/sliding-house-by-drmm-2/

[6] http://assets.inhabitat.com/files/slidinghouse_more.jpg

[7] http://projects.archiexpo.com/project-29940.html

[8] http://www.dailytonic.com/sharifi-ha-house-by-nextoffice-ir/

[9] http://www.archdaily.com/306566/absolute-towers-mad-architects

[10] http://2.bp.blogspot.com/A_TIUKXU4XQ/UJ1ByamaCXI/AAAAAAAAO6I/vCXKe5w01qI/s1600/Absolute+Towers+by+Mad07.jpg

Authors:

Assist. PhD. Arch. Ana-Maria GRAUR, Technical University of Cluj-Napoca, Faculty of Architecture and Urban Planning, E-mail: arh.anamariarusu@gmail.com, Phone: 0040264401845

Lecturer PhD. Eng. Georgiana CORSIUC, Technical University of Cluj-Napoca, Department of Building Services, E-mail: Georgiana@mail.utcluj.ro, Phone: 0040264202519.