Ana-Maria GRAUR, Dana Sorina OPINCARIU

GRAPHIC EDUCATION AT THE FACULTY OF ARCHITECTURE AND URBANISM, CLUJ-NAPOCA

Abstract: *Architecture connects science and art. Thus, the student from the Faculty of Architecture and Urbanism manifests himself as a creative being, capable of accumulating new information from various fields related to architecture, processing them, capitalizing on them and finally, through the result of creation, enriching the built environment. In their projects, technical thinking and various constructive systems are used, which are based on the training of three-dimensional thinking through descriptive geometry. This paper presents how geometric knowledge is applied in various projects within the disciplines studied at the Faculty of Architecture and Urbanism, Cluj-Napoca.*

Key words: *descriptive geometry, architectural design, applied geometry, architectural concepts.*

1. INTRODUCTION

Descriptive Geometry, Perspective and Geometry of Architectural Forms are subjects that are taught in year 1 at the Faculty of Architecture and Urbanism of the Technical University of Cluj-Napoca, Romania. They are disciplines of fundamental importance, which endow students with technical, practical knowledge and various skills on which courses that will be taught in the following years and the entire profession of architecture are based. These disciplines are the only ones that help architects communicate with each other, regardless of the language they speak, because it is an international graphic language and, of course, through it we can transpose three-dimensional objects onto a two-dimensional support.

At the beginning of the study years, in any field of design, students need to develop their intelligence, visual spatial thinking and conceptualization capacity. Architects and designers must create objects that do not yet exist. Drawing thus becomes the compositional language, essential in the field of architecture and is understood as a process of projecting order in the world [1]. Graphic thinking takes advantage of the power of visual perception by making visual images external and explicit. By putting them on paper, we give visual images objectivity outside our brain, an existence of their own over time.[2] This language generates a connection between the environment, the architectural concept, the function of the building and its structure, and each of these parts is correlated and represented by geometry. It becomes fundamental in the education of spatial vision, the interpretation of the architectural form and its description [3].

2. THEORETICAL AND PRACTICAL COURSES IN GRAPHIC EDUCATION AT THE FACULTY OF ARCHITECTURE

The preparation of students in the first year of study involves a substantial effort in their duty to design three-dimensional space. Thus, abstract thinking from descriptive geometry is a perfect environment for stimulating the perception of three-dimensional space.

In the first year of study, the use of the computer is not allowed in the realization of projects within the design disciplines, emphasizing the development of the sense of proportion given by the scale of the drawing and spaces, and freehand drawing is, above all, an active process, kinesthetic and real. For the architect student who faces the task of designing something that does not yet exist, drawing is the only way to materialize thoughts. In the Descriptive Geometry discipline, students must create works through which they practice the materialization of space. They go from point to plane and study the methods by which they can visualize special positions of these geometric elements, Figure 1.

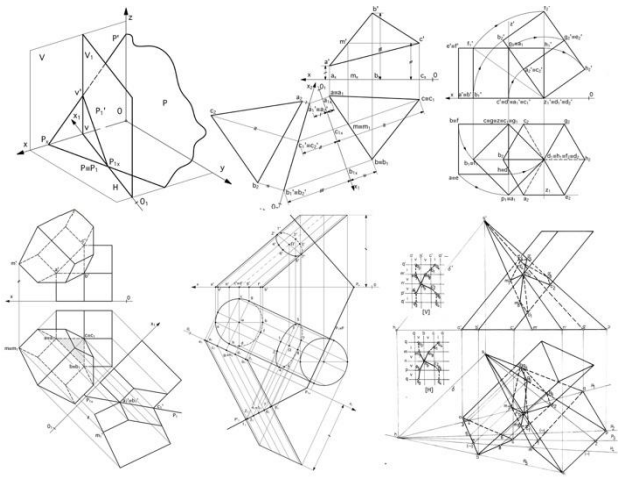

Figure 1 Descriptive Geometry applications.

The 14 courses presented throughout the semester are:

- Introductory elements. Projection systems
- Elements of descriptive geometry. Double and triple orthogonal projection of the point
- Line
- Plan I
- Plan II
- Descriptive geometry methods: The changing projection planes method

- Descriptive geometry methods: The rotating projection planes method
- Descriptive geometry methods: The rebating method
- Polyhedral surfaces. Representation. Flat sections
- Polyhedral surfaces. Unfolded geometric volumes and applications
- Cylindrical-conical surfaces. Representation. Flat sections
- Cylindrical-conical surfaces. Unfolded geometric volumes and applications
- Intersections of polyhedral
- Synthesis course.

The seminars are interactive, combining examples of exercises done on the board with applications solved individually, freehand, by the students under the guidance of the teachers, so the students will deepen and fix the knowledge taught in the course. The difficulty of the proposed exercises is designed according to the increasing complexity of the geometric phenomenon. In addition to training spatial thinking, it is important to transfer understanding of complex descriptive geometry problems, professor-student, through a step-by-step construction. The experiences of professional architects show that a combination of the geometric knowledge acquired during their studies gives them a capacity for critical analysis and an efficient approach to various geometric tasks [4].

Another important discipline is Perspective, a word that comes from the Latin language "perspicere", which means "to see clearly", it was born from the perception requirements of architecture. As we well know, the architect Brunelleschi developed the constructive principles of perspective through the use of geometric projection methods.

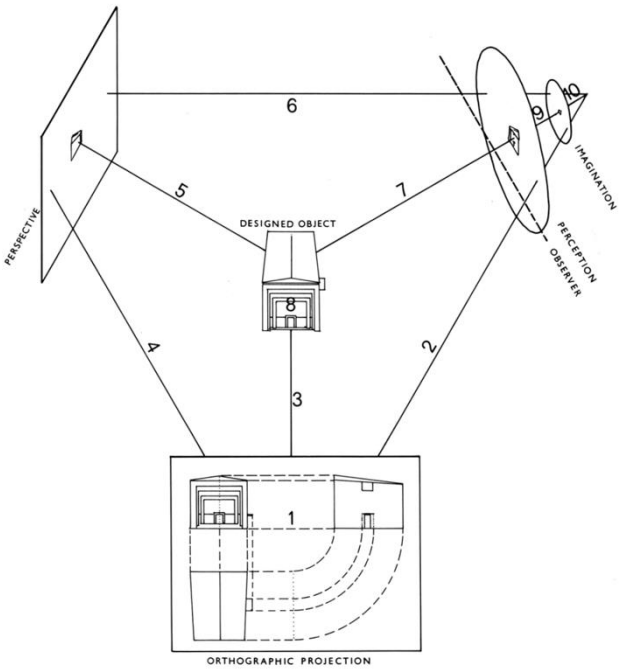

Figure 2 Diagram by Evans Diagram of projective transactions.

Today, the Architect Robin Evans, in his book "The Projective Cast Architecture and Its Three Geometries" very well redefines the relationship between geometry and architecture through mathematics, engineering, art history and aesthetics with the help of which he discovers new processes in imagining and realizing the architectural form. He presents a diagram that summarizes very well the role of geometry, perspective and imagination combined with the perception of an observer, Figure 2. He said: "Between geometry and architecture we have somehow hopped from inside the mind to outside. So when dealing with architectural geometry, we seem to be dealing with this route or doorway between mental and real" [5]. The 14 courses presented throughout the semester are:

- Introduction – Perception; Representation; Communication
- Introduction: projection systems, classifications of Perspective, the geometric mechanism of Perspective
- Brunelleschi's method of perspective construction
- Dependent perspective on vertical tableau; General principles and construction methods FF90 /OP
- Dependent perspective on vertical perspective. The methods of construction OF, FP, FM
- Free vertical perspective
- Free perspective construction methods
- History of representation in perspective
- Photography and Restitution of perspective in drawing; Architectural photography as a working tool Methods of building perspective restitution; Increasing the proportion of a perspective
- Aerial perspective; Rendering the depth of space by: Gradation of light and shade; Representation of textures; Color and ambient elements
- Shadows and mirrors in perspective
- Presentation of the architecture perspective; Array paging and bounding; Depth rendering; Unfavourable situations in choosing the perspective; The choice and placement of the entourage
- The art of scenography; The language of visual communication
- Synthesis course

As in the course of Descriptive Geometry, the seminars in this course are interactive, combining applications solved individually, freehand, by students under the guidance of teachers with small research related to various topics, so students will deepen and fix their knowledge taught in the course, Figure 3.

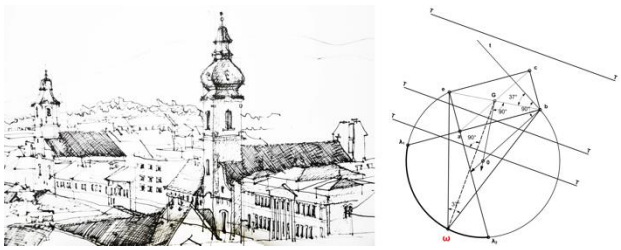

Figure 3 Perspective applications.

Another course that integrates knowledge in the field of geometry is the Geometry of Architectural Forms, where courses with increasing difficulty from simple to complex surfaces are presented, Figure 4.

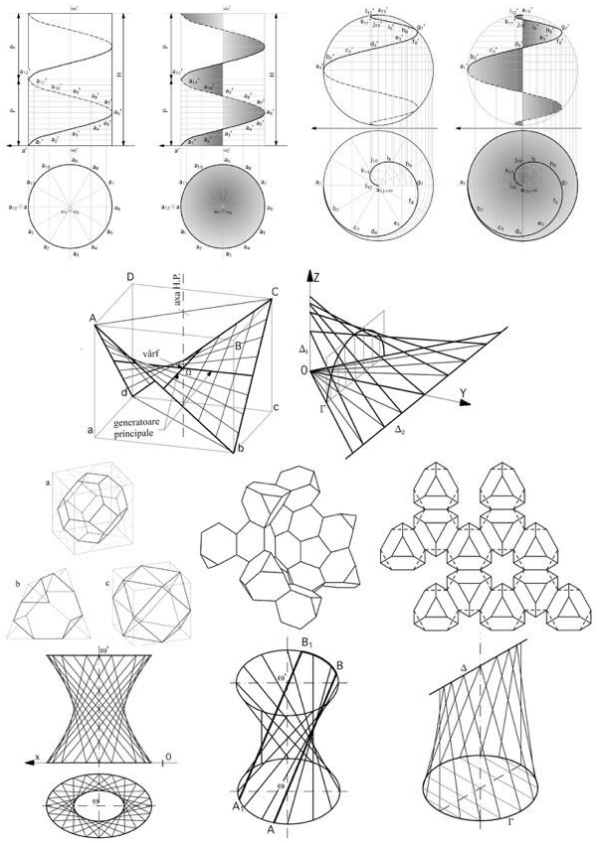

Figure 4 Geometry of Architectural Forms applications.

Each presentation of the course begins with the basic characteristics of surfaces, the method of obtaining them geometrically, planar sections and intersections.

Students learn much more easily, having architecture as their subject of study, thus to motivate them, the course continues with examples of architecture for each volume or geometric surface, and at the end examples of models of the best works made by students in the previous years. The theoretical courses take the form of debates, and the practical works in the workshop involve collaboration between students and student-teachers, helping them to imagine and design increasingly complex surfaces. The 14 courses presented throughout the semester are:

- Introductory course
- Polyhedra: irregular, regular and semi-regular
- Planar and spatial tessellation
- Circle, sphere, torus
- Geometry of vaults
- Reticulated surfaces
- Folded structures
- Ruled surfaces. Hyperboloid
- Ruled surfaces. Hyperbolic paraboloid
- Ruled surfaces. Conoids
- Ruled surfaces. Cylindroid
- Helical surfaces
- Architectural forms whose structures are resistant by form
- Forms of advanced architecture. Free surfaces
- Synthesis course

By completing the Descriptive Geometry course in the first semester of the first year, the academic year continues in the second semester with the subjects Perspective and Geometry of Architectural Forms which approach spatial thinking in a much more practical way, through practical topics for the study of perspective applied to architectural volumes or topics that have purpose of creating a temporary pavilion located in the urban space. This theme of design in relation to geometric thinking provided very interesting results and maintained a high level of motivation, which is essential for the success of the development of creativity. The materialization of the sketches in the form of models allowed the students to design the pavilion, which has as an architectural concept, the geometric volumes or surfaces studied in the Geometry of Architectural Forms course, and had a beneficial impact on the geometric understanding of the two-dimensional-three-dimensional translation of the conceived form.

3. OBJECTIVES OF GRAPHICAL EDUCATION

As Galileo Galilei (1564–1642) said, "[The universe] cannot be read until we have learned the language and become familiar with the characters in which it is written. It is written in mathematical language, and the letters are triangles, circles and other geometrical figures, without which means it is humanly impossible to comprehend a single word" [6], drawing is the compositional and essential language of architecture. This language is used to create a geometric matrix capable of satisfying both conceptual strategy, functional and structural determinations, and once the studies are completed, this knowledge will become useful. All these stages are correlated with geometric thinking, and the geometry-architecture relationship is essential in articulating the shape of the built space [7]. In the field of design, the development of visual thinking skills plays a more important role than that of verbal thinking. In the following we will detail the methods by which we can deepen this visual language.

3.1. Teaching and learning

Historically, design education began with an apprenticeship, as there was no formal design education and design was "learned by example and personal engagement" [8].

Donald Arthur Norman specifically criticizes the discipline of design, arguing that "design is still an art, taught by apprenticeship, with many myths and strong beliefs, but incredibly little evidence. We do not know the best way to design something, [9] due to the fact that it is very difficult to control a wide range of variables that involve design as a process of creation. In the following, we will try, in addition to the classical learning methods, to find new learning environments through which students can combine the classical

learning method with new methods that develop evaluative and creative thinking.

Over time, the history of design practice is one of transition from trades to professions; from purely instrumental know-how gained through employment to academic preparation that includes study of the discipline as well as the practice – that is, the theories, perspectives, and discourse that underpin professional decision-making [10]. Today, we can say that there is an "architect's method" that combines the tradition of the craftsman with this learning from the master [11].

3.1.1. Sketching

The main reason for the need to use and understand descriptive geometric representations is the one-to-one correspondence between architecture and drawing, which makes it easy to read an architectural plan or vice versa, the transcription of a building in a projective drawing. Within the Descriptive Geometry discipline, the focus is on the conscious approach to different projection modes, because architects should always be able to choose the most appropriate and reasonable design mode that suits the purpose [12].

For a student who must regularly look for new solutions to problems and who must think creatively in the graphic field, qualities such as: immediacy, stimulation, accident and contemplation are pursued. Added to these qualities is another special attribute of graphic thinking, simultaneity.

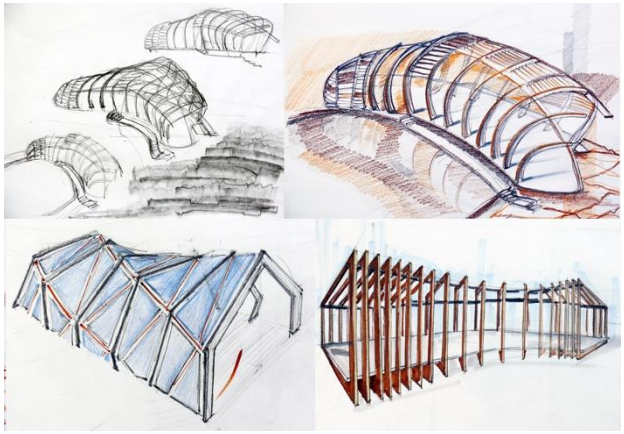

Figure 5 Sketches for the discipline Geometry of architectural forms.

During the first year of college, students must deepen their graphic thinking. Sketches allow us to see a large amount of information at once, exposing relationships and describing a wide range of subtleties. Sketches are straightforward and representative. [13] Thus, the student must develop skills in the construction of the image, artistic skills, the development of visual perception, a spatial thinking and creative imagination, Figure 5.

3.1.2. Physical modelling

After analyzing the sketches, what follows is the verification of the three-dimensional volume, that is, the verification of the functionality in three dimensions, and we can do this very easily with studio models, Figure 6. When looking for a suitable design in a project, study models, as a method of visualizing the intermediate result are effective in polishing the idea and occupy an important place in the preparation, completion phases of the project. The architectural model actually represents the transposition of the design and objectives into reality. Often, through the physical materialization of the design, we realize that there are major differences between what was sketched and what resulted in the end. Here appears a sustained cognitive commitment to learning new geometric structures and shapes, which requires the understanding of complex structures and the mastery of three-dimensional modelling skills, a previously thought structure on a two-dimensional work support. This process boosts learning and the transfer of knowledge from teacher to student through practical activities.

Figure 6 Models.

3.1.3. The use of technology

Visual communication is evolving towards radical changes through computerized technologies that offer the designer new graphic tools. In these conditions, graphic thinking is a basic tool that opens new communication channels. Although in the 1st year it is not allowed to use the computer in the realization of architectural projects, digital techniques can be considered helpful tools in the phase of creating the architectural form, in addition to geometry and perspective, Figure 7a.

Figure 7a 7b Student workshops.

It is hoped that in the future we will generate a new pedagogy of design thinking to address two vital requirements: ensuring that students learn to engage in flexible, creative and critical thinking that enables them to pivot and adapt responsively in any situation; and students also need to be reflective enough to collaborate in various social constructs and settings so that they are equipped for uncertainty [14]. In these conditions, the generation of architectural solutions based on descriptive geometry, involves minimal knowledge of the structure of buildings, a domain mastered by engineers. We are dealing with an interdisciplinary approach to design processes.

3.1.4 Practical work. Studio

Karla Straker summarizes the students' skills acquired in the workshop practical works, which allow them to: develop alternative points of view; explore multiple solutions iteratively; understand ways to approach "wicked problems"; clearly communicate ideas and strategies; critically assess current situations and environments; synthesize strategies for innovation [15]. Thus, during the workshop, the students exhibited their documentation, drawings, sketches and three-dimensional study models for an intermediate discussion, presenting the solutions found to their colleagues and the teacher, Figure 7b.

The fact that classmates also participated in the discussion, many students shared ideas with each other, projects were compared and the time spent searching for a solution was shortened by using creative thinking. This stage of the intermediate discussion in the workshop provides new information and fuels the understanding of the geometric shapes and structures addressed. When students analyse the work of others, during the corrections in the workshop, they inevitably arrive at comparative evaluations with the personal project, which determines the improvement of the solution, where appropriate [16].

Schön mentioned the reflexive practice that encourages discourse and reflection during the design process, calling it "thinking through action" and suggests the effort invested in developing different design alternatives, helping those involved in the process to compare and judge important aspects of the project [17]. The research also suggests that a peer-to-peer evaluation and exchange of suggestions on the project involves the students in multiple judgments. Students discover strong or weak points in their own project and become self-critical of their own solution, in comparison with those of their colleagues, perfecting their judgment skills [18], Figure 8.

Over the past two decades there has been a move in education away from traditional, teacher-directed, instructionist teaching towards progressive, student-centred, constructivist learning. […] Students are motivated through the process of learning by following their own interests, and that they assess their learning by setting their own targets, monitoring their own progress, and completing self-evaluations.

Figure 8 Final results of the workshops.

Individual students are supported through this process by teachers, from across various disciplines, who provide a framework to assist students to go beyond blockage points in their learning. Thus, the ability to adapt to new challenges and changing situations is developed [19].

4. CONCLUSIONS

The increase in the density of cities, the diversity of contemporary life requires complex spatial configurations that allow the unfolding of a wide range of scenarios. More than ever, graduates must have the necessary training to adapt to the complex challenges they will face in their professional activity, taking into account multiple perspectives, which will allow evolution. Under these conditions, education must ensure interdisciplinarity, developing in this way innovative skills and capacities. Without a curricular plan developed in this direction, pupils and students have no way to acquire these skills. The teaching of graphic subjects is a great necessity in the training of students at the Faculty of Architecture and Urbanism, Cluj-Napoca University of Technology, Romania. Through the results of their projects, they showed that they learned not only to recognize geometric surfaces in architectural objectives, but also to apply them in the design of architectural concepts. Through courses, practical works and workshop exercises, the students were able to follow the theoretical and practical foundations of descriptive geometry that will provide the basis for the development of creative thinking. In order to make the cognitive geometric process more efficient and to stimulate the students' critical ability, it is necessary to combine real, practical experiences with geometric analysis, descriptive and constructive methods. These exercises stimulate creativity and offer new directions for approaching forms and concepts in architectural design.

REFERENCES

[1] Cooper, D. "Drawing and Perceiving: Life Drawing for Students of Architecture and Design", 3rd Edition, Wiley, New Jersey, United States, pp.4, 2000.

[2] Laseau, P. "Graphic Thinking for Architects and Designers" Wiley, New Jersey, United States, pp. 9, 2000.

[3] Cumino, C., Pavignano, M., Spreafico, M.L. et al. "Geometry to Build Models, Models to Visualize Geometry", Digit Exp Math Educ 7, pp. 149–166, 2021. https://doi.org/10.1007/s40751-020-00080-6

[4] Pütz, C. “Teaching descriptive geometry for architects: didactic principles and effective methods demonstrated by the example of Monge projection”, In: International Conference on Graphics Engineering for Arts and Design, Sao Paulo, Brasil, pp. 271, 2001.
[5] Evans, E., The Projective Cast Architecture and Its Three Geometries, MIT Press, United States, p.354, 2000.
[6] Galilei, G., Il Saggiatore, nel quale con bilancia esquisita e giusta si ponderano le cose contenute nella Libra astronomica e filosofica di Lotario Sarsi Sigensano, Roma, pp. 171, 1623.
[7] Ana-Maria GRAUR, Carmen MÂRZA, Georgiana CORSIUC, The use of twisted surfaces as a source of inspiration in architectural concepts (Journal of Industrial Design and Engineering Graphics) vol. 17, no. 1, ISSN 2344-4681, pp.37-42, 2022.
[8] Wrigley, C. Mosely, G. "Design Thinking Pedagogy. Facilitating Innovation and Impact in Tertiary Education", Routledge, London, pp. 9, 2022 https://doi.org/10.4324/9781003006176
[9] Fisher, K. “The Translational Design of Learning Environments”. In: Fisher, K. (eds) The Translational Design of Schools. Advances in Learning Environments Research. SensePublishers, Rotterdam, pp.4, 2016. https://doi.org/10.1007/978-94-6300-364-3_12016
[10] Davis, M. “Teaching design: A guide to curriculum and pedagogy for college design faculty and teachers who use design in their classrooms”. NY: Allworth Press, New York, pp. 5, 2017.
[11] Danchenko, L., Tuktamyshov, N. "A modified design-analog method of teaching geometry and graphics as a means of integrating of training and design activities of future architects" In: IOP Conference Series: Materials Science and Engineering, pp. 3, 2020 doi:10.1088/1757-899X/890/1/012170
[12] Brakhage, K. Pütz, C. "A Didactical Concept for the Computer-Aided Demonstration of Different Ways of Projection Used in Descriptive Geometry". In: Proceedings of The 8th International Conference on Engineering Computer Graphics and Descriptive Geometry, pp. 617-621, Austin, Texas, United States, 1998.
[13] Laseau, P. "Graphic Thinking for Architects and Designers" Wiley, New Jersey, United States, pp. 9, 2000.
[14] Wrigley, C. Mosely, G. "Design Thinking Pedagogy. Facilitating Innovation and Impact in Tertiary Education", Routledge, London, pp. 23, 2022 https://doi.org/10.4324/9781003006176
[15] Wrigley, C. Mosely, G. "Design Thinking Pedagogy. Facilitating Innovation and Impact in Tertiary Education", Routledge, London, pp. 70, 2022 https://doi.org/10.4324/9781003006176
[16] A.M. Graur, A.E. Voinea, A.M. Oprică Geometry and its application in the concepts of architecture students' projects, ICERI2023 Proceedings, pp. 1780-1786, 2023.
[17] Schön, D. A. “The Reflective Practitioner: How Professionals Think in Action”. New York, NY: Basic Books, pp. 170, 1983.
[18] Zhu, Q. Carless, D. “Dialogue within peer feedback processes: clarification and negotiation of meaning”, Higher Education Research & Development, 37:4, pp. 883-897, 2018. DOI: 10.1080/07294360.2018.1446417
[19] Woodman, K. Re-Placing Flexibility. In: Fisher, K. (eds) “The Translational Design of Schools. Advances in Learning Environments Research”. SensePublishers, Rotterdam, pp. 51-52, 2016. https://doi.org/10.1007/978-94-6300-364-3_3

Authors:

Lecturer Ph.D. Arch. Ana-Maria GRAUR,
Technical University of Cluj-Napoca, Faculty of Architecture and Urban Planning,
E-mail: Anamaria.Graur@arch.utcluj.ro;
Assoc. Prof. Ph.D. Arch. Dana Sorina OPINCARIU, Vice Dean, Technical University of Cluj-Napoca, Faculty of Architecture and Urban Planning,
E-mail:Dana.Opincariu@arch.utcluj.ro