INTRODUCING 3D MODELING INTO GEOMETRY EDUCATION AT TWO TECHNICAL FACULTIES AT THE UNIVERSITY OF ZAGREB

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ABSTRACT: In this paper we present how 3D computer modeling is introduced into the teaching of Descriptive geometry and Perspective courses at two technical faculties at the University of Zagreb.

Keywords: geometry education, 3D modeling, Rhinoceros, e-learning

1. INTRODUCTION

Teaching constructive geometry, mainly within the courses of descriptive geometry, has a long and well-established tradition at the technical faculties in Croatia. But, excluding the University of Rijeka, long-time insistence on the traditional way of teaching resulted in lagging behind most countries of European Union in the application of computer 3D CAD packages and implementation of educational content in e-learning systems at the beginning of 2012. During the year 2012 the authors, together with nine other teachers, worked on the project *Introducing 3D Modeling into Geometry Education at Technical Colleges* supported by the Fund for the Development of the University of Zagreb. The focus of the project was creating a basic repository of educational material related to common teaching topics and those customized to profiles of each faculty (`http://www.grad.hr/geomteh3d/`). The content of this project is described in detial in [2].

In this paper we present a part of the educational material, made within the aforementioned project, related to 3D computer modeling with the program *Rhinoceros* and our experience of using this material in teaching descriptive geometry courses at the Faculty of Civil Engineering (FCE) and the Faculty of Mining, Geology and Petroleum Engineering (FMGPE) through last two academic years.

2. DESCRIPTIVE GEOMETRY COURSES

In aforementioned faculties, teaching of Descriptive geometry is held in first year of study: (2+3) in 1st semester at FCE, (2+2) in 1st and 2nd semester at FMGPE. For most of the students, this is their first encounter with this subject. The course contains two separate parts. In the first part, students work with a ruler and compasses and are introduced into the method of Monge projections. Constructive procedures are being explained in detail and students are consequently capable to construct orthogonal projections of simple geometric objects (prisms, pyramids, cones and cylinders) in general position to the planes of projections. After that, basics of axonometry are being taught and students draw in hand one simple object. Meanwhile, in exercise classes, they draw axonometric images of more complicated objects using *Rhinoceros*. Afterwards, all matter being taught in lectures is also constructively handled in this program.

Rhinoceros was chosen for a few reasons: a good experience of colleagues from the University of Innsbruck, a relatively low cost of the educational lab licence and the free trial versions available for students' downloads. Due to the lack of time, students are not taught basics of *Rhinoceros* in exercise classes. For that matter, the repository (that is made within the aforementioned project) contains more than 50 five-minute video clips in which constructions in

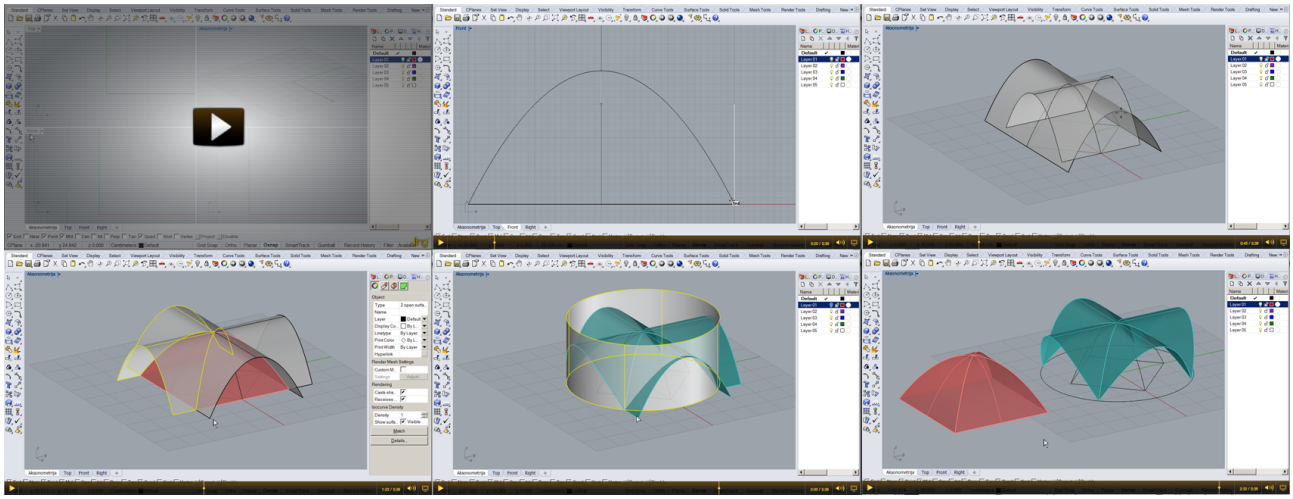

Figure 1: Screenshots from the video clip related to the intersection of parabolic cylinders.

Rhinoceros are being explained.

The video material was produced using free online program *Jing* which creats five-minute videos with sound. Using these video clips, students are introduced to the basics of the program *Rhinoceros* on their own, while they still draw in hand in class. For each of the later teaching unit, students are given a few solved representative examples so they can master the program by themselves. In this manner, we achieved the following: students work at home to learn the program and then come to the exercise classes and solve geometric problems concerning descriptive geometry.

All of the teaching material created is organised in teaching units and is available online on e-learning web pages. University of Zagreb developed this pages using e-learning platform Merlin, the system based on the learning management system Moodle. Our application of e-learning has level 2, but in some segments level 3, [1]. On these web pages students can also find information about their grades. We grade their exercises and mid-term exams. Due to the relatively large number of students (each teacher handles cca 50 students), we refused to use the option for uploading student exercises. That would diminish our control over their work and the communication about their work would be more complicated. Because of that, we only grade exercises solved in class in front of the teacher, or optionally in teacher consultations. Each exercise class is graded.

Each student workgroup in computer lab has 10-12 students. This number allows the teacher to have good insight in the work of each student, gives the teacher the ability to examine acquired knowledge and deepen it if necessary, according to individual needs of every student. For each lesson, a student is given a few exercises (mostly 3) in advance. He/she prepares solutions to these exercises at home before class. If he/she successfully solves these exercises and answers a few questions regarding the material being taught, he/she is graded good (C). To receive a higher grade, the student must solve one or two additional exercises given in class by the teacher. Duration of the computer lab class is 60 minutes.

Topics managed in *Rhinoceros* are: solid modeling, cross sections of surfaces, intersection of surfaces and terrains with roads and layers. Some examples are shown in figures 2-5.

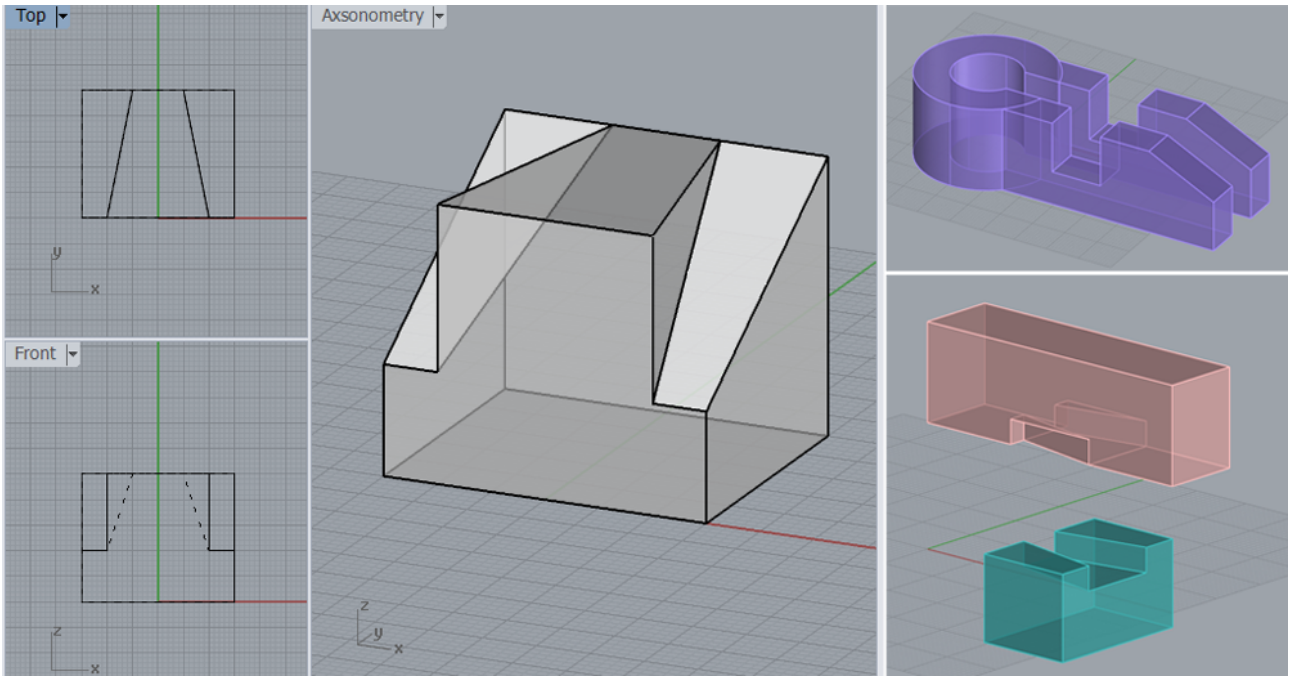

Figure 2: Three solved examples for solid modeling. Students are given two principal views of the object and their objective is to construct its axonometric image in *Rhinoceros*. This is the content of the first lesson in the computer lab.

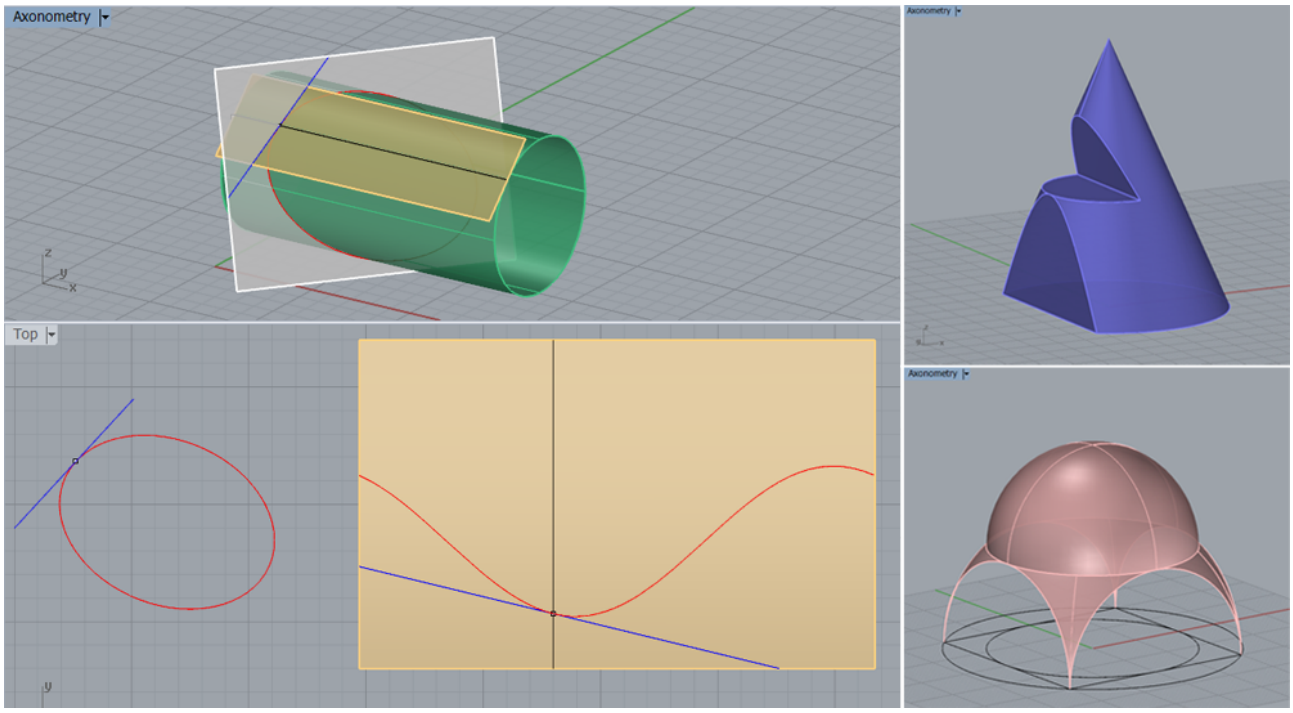

Figure 3: Solved examples for intersections of surfaces and planes. In this topic students handle cone, cylinder and sphere sections, tangent planes of these surfaces and tangents of intersection curves.

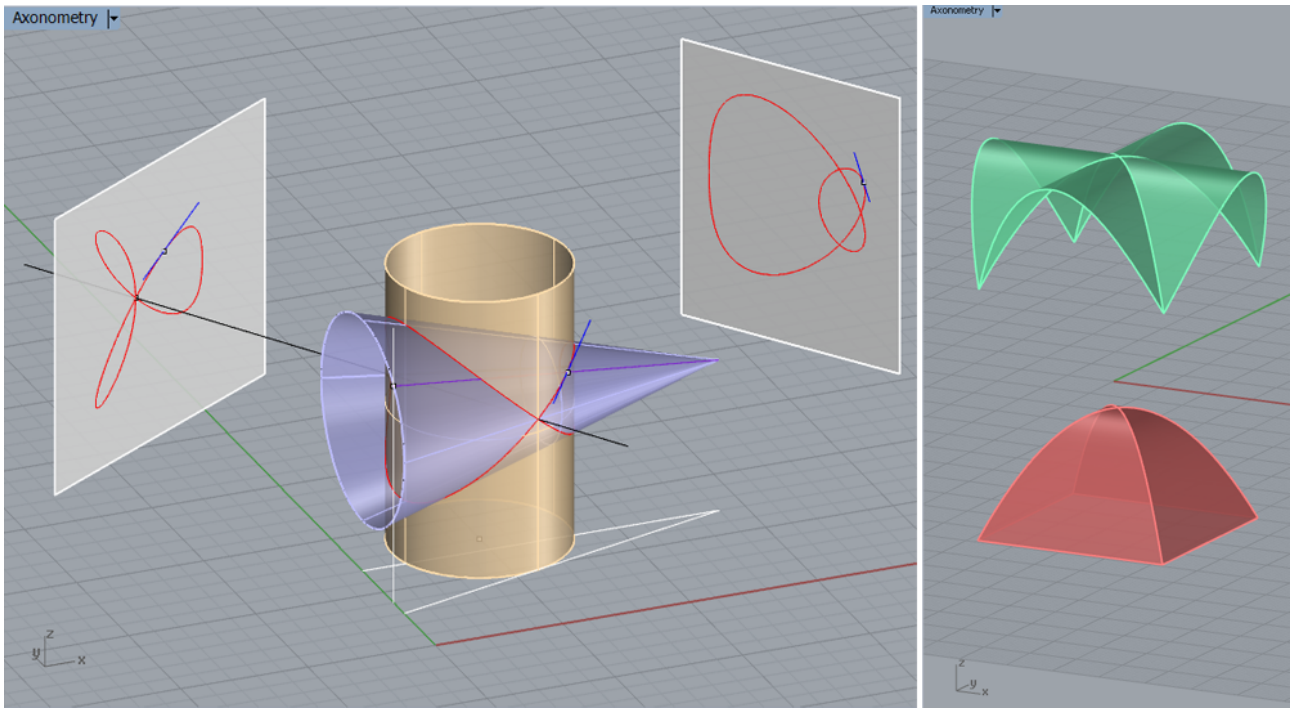

Figure 4: Two solved examples for intersections of surfaces. We deal with intersections of cones, cylinders and spheres, the tangents, plane projections and splitting of intersetion curves.

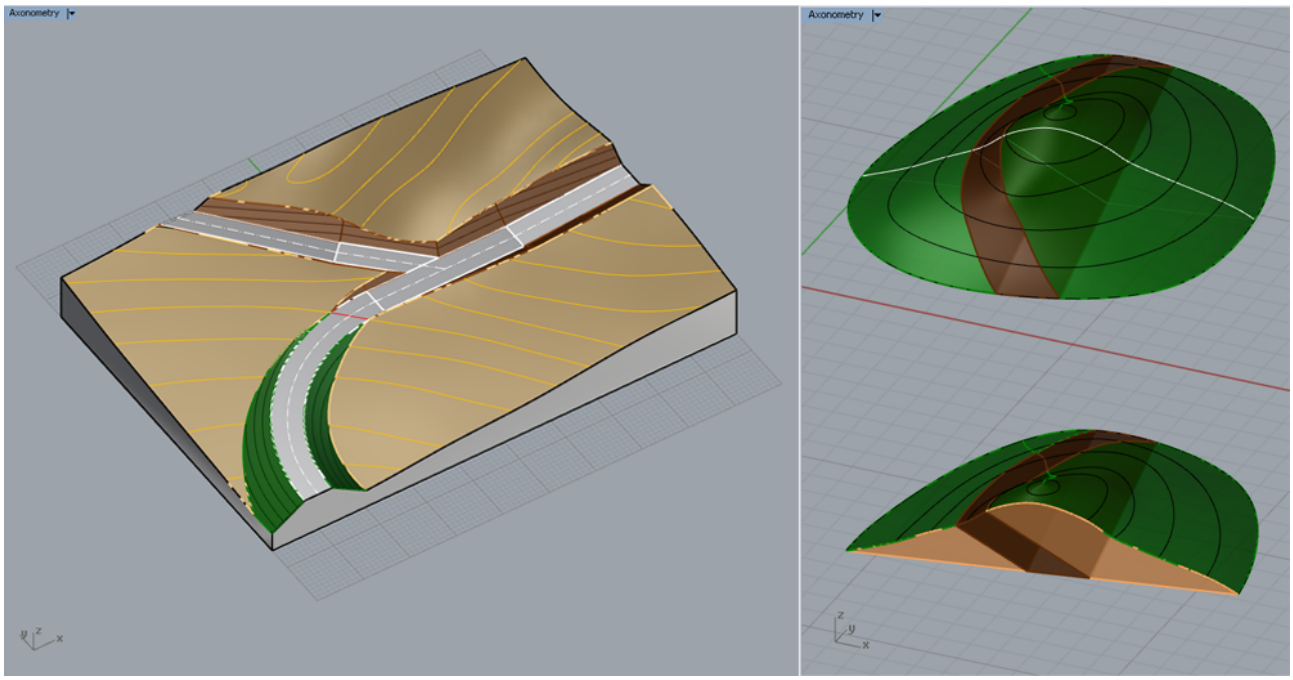

Figure 5: Examples of solved exercises for the situation of earthworks beside the road on the terrain and layers on the terrain. Before they model these exercises in *Rhinoceros*, students learn about the projection with elevations and solve the same exercises in hand in this projection method.

3. OPTIONAL GEOMETRICAL COURSE FOR MASTER STUDENTS

A decade ago, when Bologna Process caused educational reform in Croatia, geometry teachers of Department of Mathematics at FCE suggested two optional courses for master students: Basics of differential geometry and Perspective. Until now, students showed no interest in the first course - we believe this is because it contains ample amount of higher mathematics, while Perspective aroused certain attention. In period 2009-2012, each academic year 7-9 students enrolled in Perspective. The content of this course included the following: basics of perspective, construction of perspective images of rooftops, ruled surfaces, roads on the terrain. These constructions were made in hand or in some CAD program in 2D.

When we implemented computer 3D modeling in teaching first year courses in academic year 2012/2013 , we did the same in Perspective. In that first year, students already showed greater interest in that course (12 students enrolled). Next academic year 2013/2014 that course had 34 students, mostly from Structural engineering and Transportation engineering programme.

Students who enroll in this course are in majority in their last semester of master programme during which they have never encountered 3D computer modeling before. That is the reason we can use our educational material prepared for the course Descriptive geometry in teaching Perspective. When generations which were taught 3D modeling in their first year of studying come to master level, our plan is to introduce *Grasshopper* as well as the basics of *Pyton* scripting for *Rhino* and *Grasshopper* (only on the informational level).

Perspective is being taught in the final semester of master programme, so by FCE's decree, whole class is held during 8 weeks, giving the students enough time to prepare their theses. Hence, work is very intense (8 classes per week) and workgroups consist of 8-9 students.

During first two weeks, students are introduced to the basics of perspective drawing and are enabled to construct perspective images of simple geometric objects. In third week, 3D modeling is introduced and they construct perspective images of objects using program *Rhinoceros*. During next two weeks, students are acquainted with quadric surfaces and ruled surfaces with emphasis on quadric ruled surfaces. Furthermore, examples of these surfaces in civil engeneering are shown and they are acquainted with geometric interpretation and visualisation of notions of differential geometry of these surfaces (notions such as classification of points on a surface, principal curvatures, normal curvature, principal directions). In sixth week the topic is conoids of third and fourth order. During last two weeks, students model situations of earthwork beside roads on terrains.

This course is optional, held in the final year of studies and has very small study groups so the concept of exercises and homework assignments differs a lot from Descriptive geometry. In classes students solve exercises available online. Working version of the collection of exercises (in Croatian) is available on line `http://www.grad.hr/sgorjanc/perspektiva-vjezbe.pdf`. Homework assignments are graded. They are made by students at home and uploaded over system Merlin. For four of these assignments only the topic is given (solid, dome and vault, coverings with quadric ruled surfaces, coverings with higher degree conoids) so a student has the liberty to choose which object (something they know from real life or something imaginary) he/she will model. In the beginning of each week, we give an overview of all homework assignments from the week before. Students enjoy this very much because it inspires them and induces cooperation. The last assignment is to model given road on a terrain. This is done in class and immediately uploaded to Merlin. If there is something left to finish, the student can finish this assignment at home and upload it again. Some examples of student homework assignments are shown in figures 6 - 10.

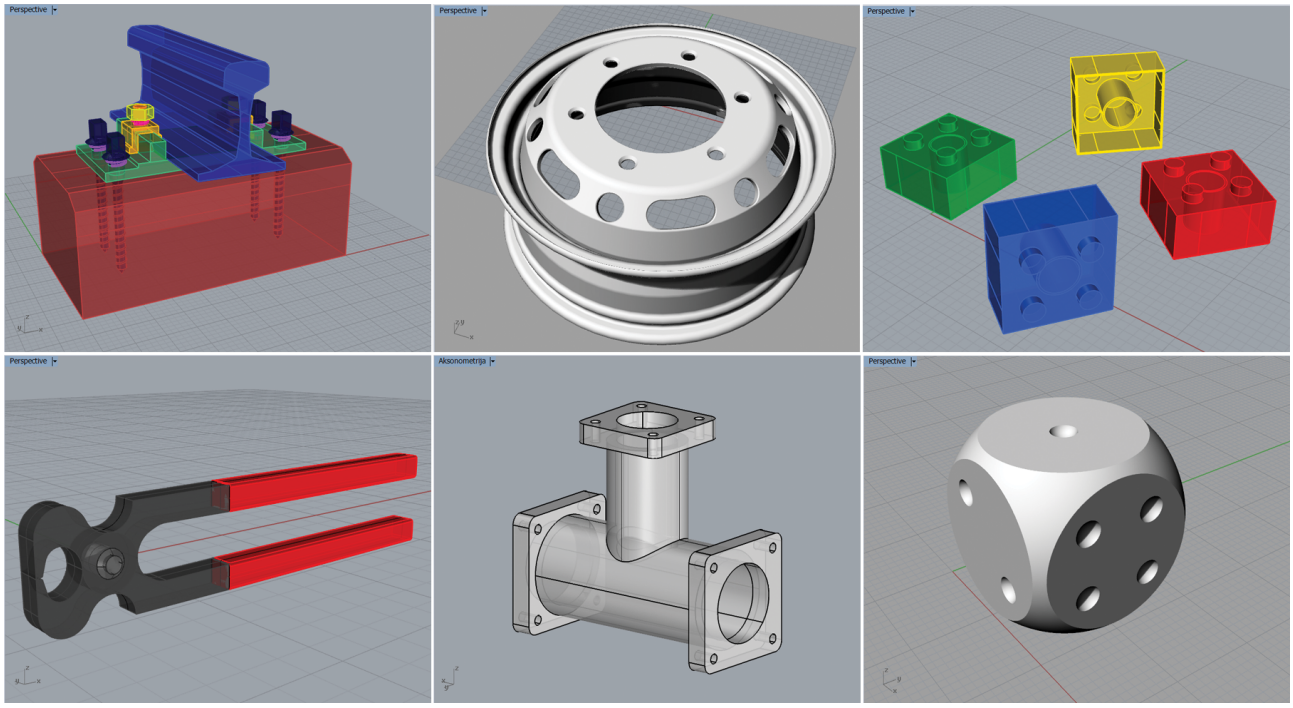

Figure 6: Student homework assignments on the subject *solids*.

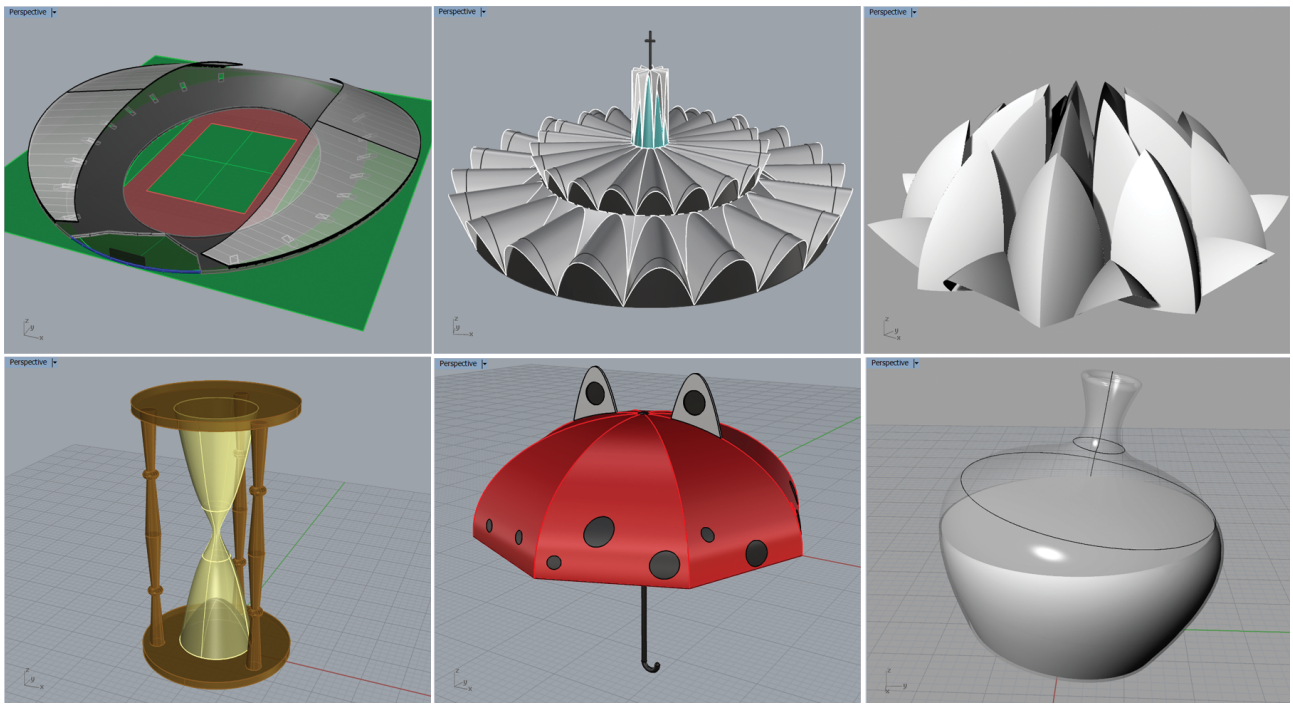

Figure 7: Student homework assignments on the subject *surfaces of revolution, domes and vaults*.

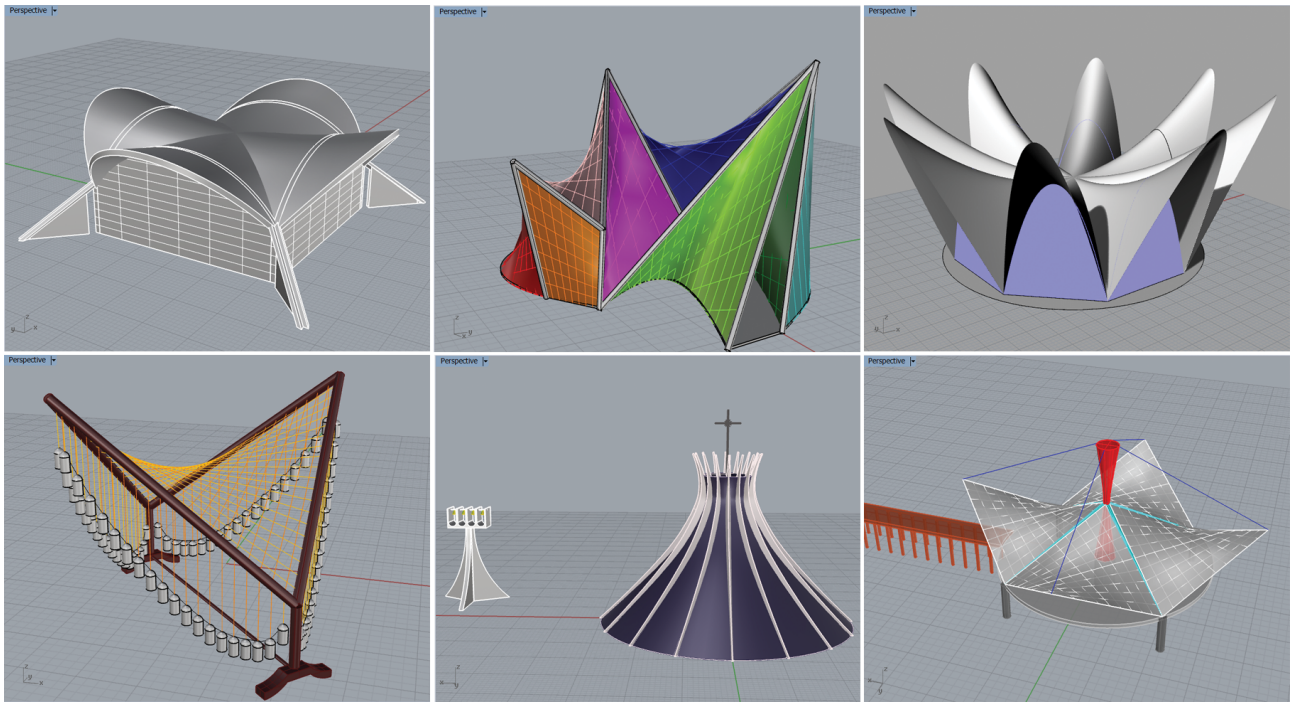

Figure 8: Student homework assignments on the subject *hyperbolic paraboloid and hyperboloid of one sheet*.

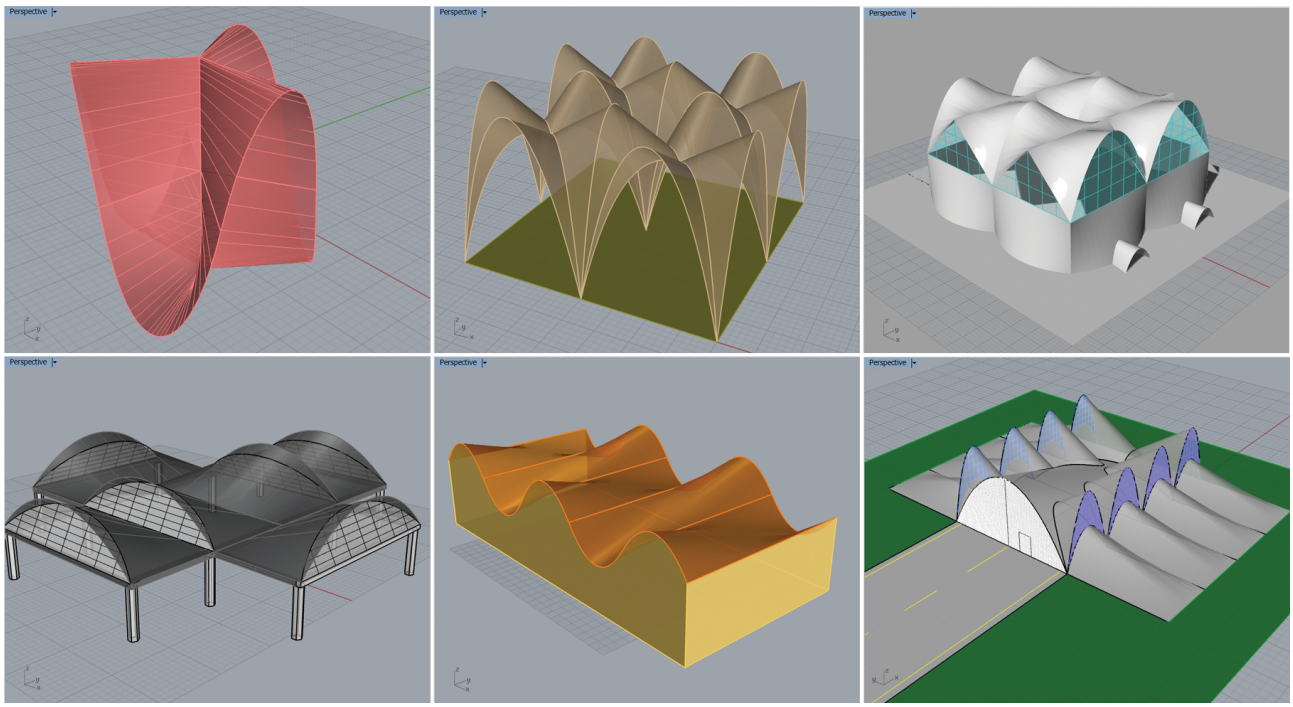

Figure 9: Student homework assignments on the subject *3rd and 4th order conoids*.

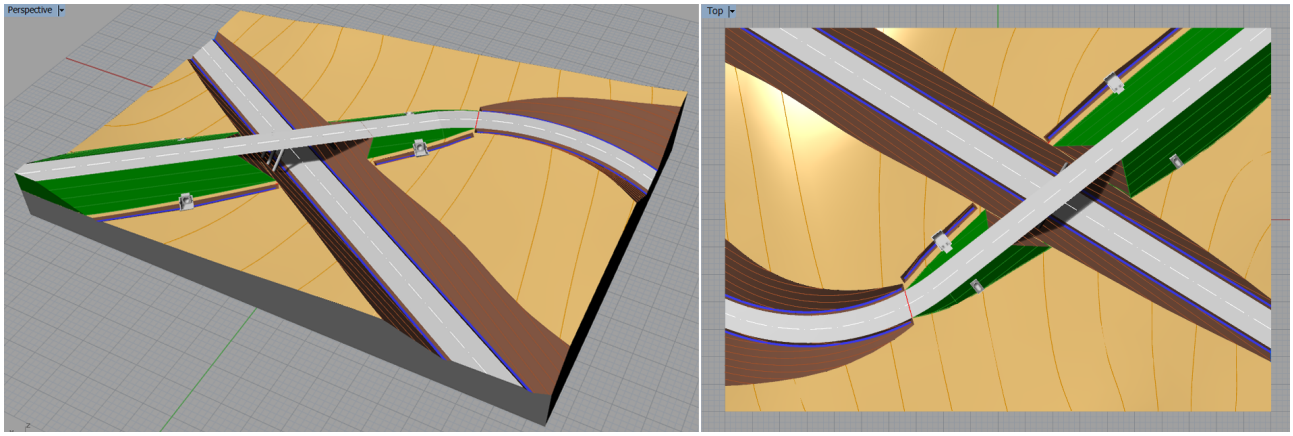

Figure 10: Student homework assignment related to *earthworks beside the road on the terrain*, made by student Šime Bezina.

4. CONCLUSIONS

As stated in the Introduction, because of subjective reasons, University of Zagreb introduced 3D modeling in teaching geometry at the technical faculties much later than other European countries which traditonally nourish descriptive geometry as inevitable segment of education for engineers. However, foreign experience enabled our current teachers to master computer-aided geometry teaching very quickly and on a satisfactory level. We were able to use plenty of positive experience from our colleagues (mostly from Austria), and we could rely on advanced technology and methodology. Regarding all of that, we avoided many possible beginner's errors. Our greatest inspiration were thoughts stated in the last section of the article [3].

Here we would like to point out some of our positive expirience:

- Resulting repository of educational material, made within the project mentioned in the Introduction, is of high quality due to the collaboration of teachers from four different technical faculties.

- Free access to the repository has had positive effect on a wider teaching community.

- Video meterial for mastering basics of the CAD program allows students to learn independently at their own pace. On the other hand, it enables teachers, who create that material, to connect students' learning programing functions with their acquiring the knowledge of geometry.

- Homework assignments which are given only by the theme and give the student freedom to choose the object they would like to model are proven to be very inspiring and they evoke creativity within students. Such assignments make students search geometrical properties in their surroundings, and they can be used as a source of ideas for future excercises.

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