

Introducing 3D Modeling into Geometry Education at Technical Colleges

Sonja Gorjanc and Ema Jurkin

Abstract In this paper we present the aims and the results of the project *Introducing 3D Modeling into Geometry Education at Technical Colleges* that was supported by the Fund for the Development of the University of Zagreb. The main goals of the project were achieving a stronger professional and scientific collaboration among teachers and improving teaching geometry courses at the technical faculties of the University of Zagreb. The focus of the project was creating a basic repository of educational materials related to common teaching topics and those customized to the profiles of each faculty. The special emphasis was given to the materials connected to 3D computer modeling.

1 Introduction

During the year 2012 twelve 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 [5]. Four faculties were included: Faculty of Architecture, Faculty of Civil Engineering, Faculty of Geodesy and Faculty of Mining, Geology and Petroleum Engineering.

The main goals of the project were achieving a stronger professional and scientific collaboration among teachers and improving teaching geometry courses at the technical faculties of the University of Zagreb. At the present stage of technological development, the introduction of computer 3D modeling is significant as well as its implementation in e-learning necessary to maintain the traditional high-

S. Gorjanc (✉)

Faculty of Civil Engineering, University of Zagreb, Zagreb, Croatia
e-mail: sgorjanc@grad.hr

E. Jurkin

Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb
Zagreb, Croatia
e-mail: ema.jurkin@rgn.hr

quality of teaching geometry to future engineers at the University. Due to the importance of the spatial ability, visual thinking and graphical presentation in the education of future engineers, geometry is still an important part of the basic education of engineers.

Teaching constructive geometry, mainly within the courses of descriptive geometry, has a long and good tradition at the technical faculties in Croatia. But 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. We believe that with this project we connected the benefits of classical and modern approaches to teaching geometry.

The project was organized as a framework for teacher training within which (by enriching professional knowledge and experience) we worked on the methodology for introduction of computer modeling in teaching geometry, on the coordination of standard educational materials and on the harmonization of access to e-learning for geometrical courses of the aforementioned faculties.

The University of Zagreb supports and actively encourages e-learning at all levels of higher education. In its e-learning strategy [8] e-learning was defined as a process of education (learning and teaching process) conducted using the information and communication technology which improves the quality of the process itself and the quality of its result. As a rule, the mixed (blended, hybrid) form of e-learning is applied at the University of Zagreb. This approach combines classical teaching methods and those used in virtual learning and teaching environments. Each faculty should recognize the form of e-learning that is most appropriate for particular study program and it should also choose the intensity of e-learning, [1].

The Office for E-learning at the University of Zagreb is situated at the E-learning Centre at the University Computing Centre of the University of Zagreb. The Centre performs all tasks for the Office with the purpose of efficient introduction and implementation of e-learning at the University of Zagreb. It has developed e-learning platform *Merlin*, the system based on the learning management system *Moodle*.

The University of Zagreb distinguishes three levels of application of e-learning technology with the following aims [7]:

- Level 1—to provide access to information about the course, to allow the use of the elected teaching materials and to facilitate communication with students.
- Level 2—to facilitate the acquisition of knowledge by the integration of e-learning with a classical teaching methods.
- Level 3—to make a shift in the educational process from the model based on transferring knowledge from teachers to students, to the model focused on the students and on the development of their own competence.

One of the results of the project was creating sites for e-learning courses at all four faculties participating in the project. The application of e-learning technology at those sites is at the level 2, and in some segments at the level 3. All teaching materials are organized according to teaching units and is available through the

system for e-learning. The courses are organized in a way that allow the individualization of the teaching process, and the environment in which students take an active role and responsibility for achieving educational outcomes.

2 Introducing 3D Modeling into Geometry Education at Technical Colleges

The goals of the project were:

- Strengthening the professional and scientific cooperation among the faculties in the area of technical sciences.
- Developing teaching methodology for 3D computer modeling to enhance geometry courses.
- Harmonization of educational material standards and their further implementation in the e-learning systems of the aforementioned faculties.

The focus of the project was creating a basic repository of educational materials related to common teaching topics and those customized to profiles of each faculty. The special emphasis was given to the materials connected to 3D computer modeling.

Until the academic year 2012/2013 *Descriptive geometry* as a course at the faculties of the University of Zagreb was mostly lectured in the classical way by using rulers and compasses. Since then the *Rhinoceros* program has also been included in the instruction of the aforementioned course at the Faculty of Civil Engineering and the Faculty of Mining, Geology and Petroleum Engineering.

The basic educational materials repository is available at the site of the project [5]. This repository contains the materials for lectures, exercises and independent learning. It refers to the following main teaching topics:

- Plane geometry (extended Euclidean plane, conic sections, transformations of the plane).
- Space geometry and methods of projections (extended Euclidean space, solids, orthogonal projections, axonometry, projection with elevations).
- Space geometry and 3D computer modeling (introduction to software *Rhinoceros*, solid modeling supported by *Rhinoceros*, surfaces, intersections of surfaces with planes, intersections of two surfaces, terrains).
- Linear perspective.
- Shades and shadows.
- Differential geometry.

The education materials related to the plane geometry contain the interactive files supported by *GeoGebra*, while the educational materials related to the space geometry contain the visualizations and animations supported by *Mathematica*. These two softwares were used only by teachers for producing the materials, the

students did not have to learn how to use them. But the students had to learn the basics of using *Rhinoceros*. Therefore, the repository also contains about 50 five-min videos helping to learn basics of *Rhinoceros* 3D modeling. These videos also prepare students for problem solving exercises in the computer lab. The videos are produced by *Jing*, a free screencasting computer program which also allows recording the voice of the teacher.

The basic information about the interface, views, viewports, construction plane, work with layers and plane and space constructions and transformations are provided through thirteen videos. Every time when we wanted to teach students something about the *Rhinoceros*, we used a geometry example, therefore students learned something about the program and geometry at the same time. The intention was to spend as little time as possible on teaching software and spend more time on using software for solving geometry problems. So, in 2 weeks, students had to learn the basics of *Rhinoceros* on their own by watching videos at home or in the computer lab. After 2 weeks they had exercises with the teacher in the computer classroom where they had to use their knowledge to solve problems typical for descriptive geometry. *Rhinoceros* was integrated in the following topics: the solid modeling, the surface modeling, the intersection of a surface and a plane, the intersection of two surfaces, the topographic surfaces, the terrain with the roads and layers (Figs. 1, 2, 3, 4, 5, 6, 7).

The reactions of the students were very positive. They liked working with computers. Some of the students had the problems with visualization of the space situation and *Rhinoceros* helped them to understand spatial geometrical relationships. They also liked videos since that material enabled them to master basic commands quickly and used those commands in solving tasks in class. The types of tasks that students solved in class are shown in Figs. 8, 9, 10, 11 and 12. Students always solved several tasks which they had been given earlier and some new tasks given by the teacher on the spot. Last year the results that students achieved in 5 weeks (2 h per week) were very good.

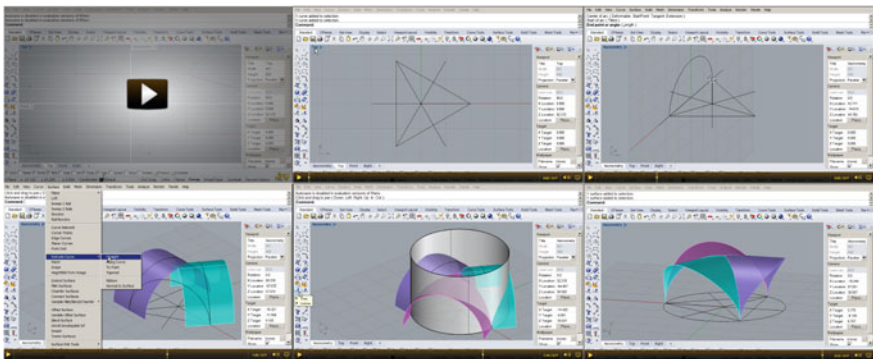


Fig. 1 Screenshots from the video related to the intersection of cylinders

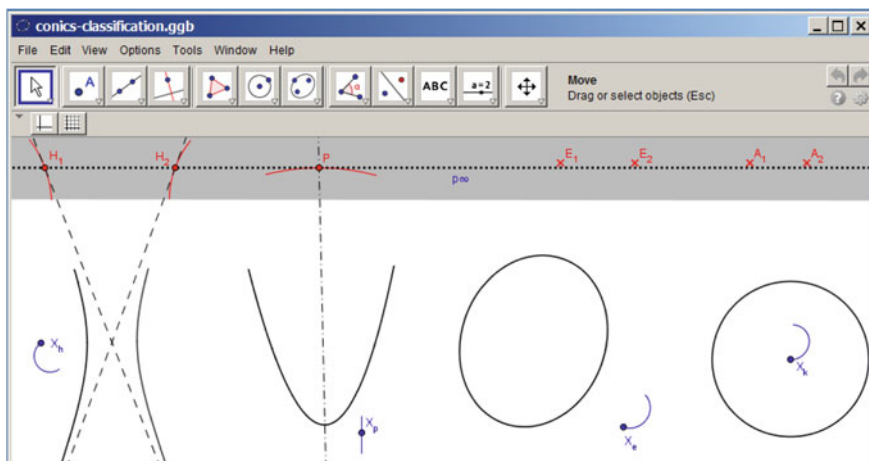


Fig. 2 A screenshot from one dynamic *GeoGebra* file that we use to illustrate the classification of conics in the extended Euclidean plane. A user can change the position of a conic

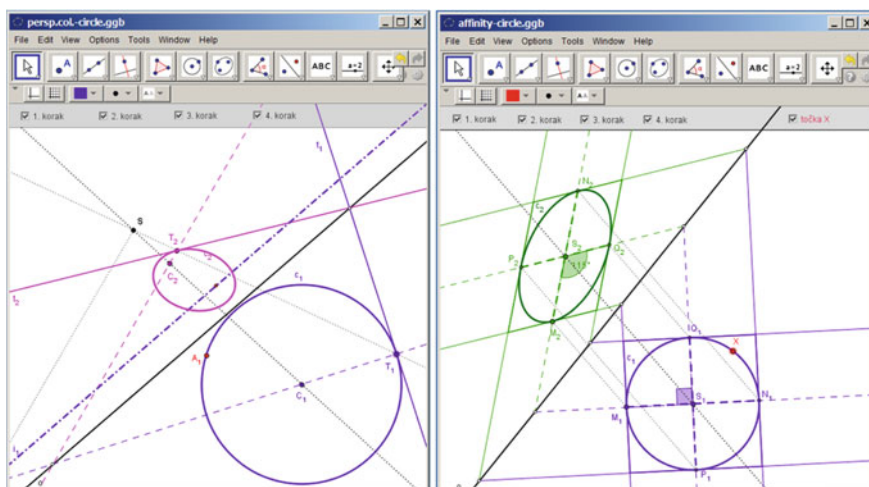


Fig. 3 Screenshots from dynamic *GeoGebra* files related to the image of a circle under a perspective collineation and affinity. Teachers and students can change the parameters of circles and transformations

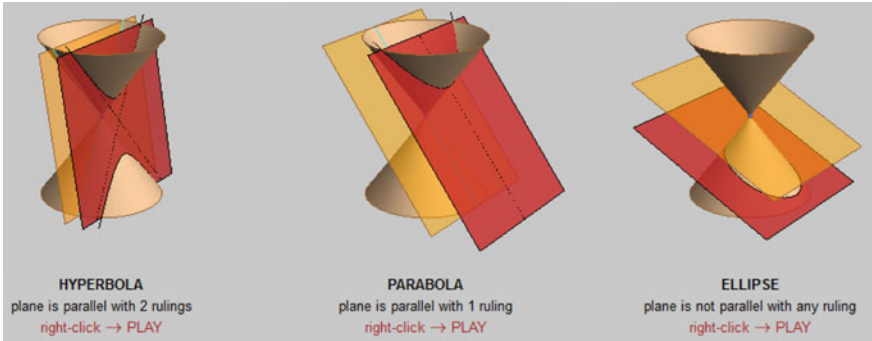


Fig. 4 The visualization of the proper intersections of cones and planes by using *Mathematica* animations

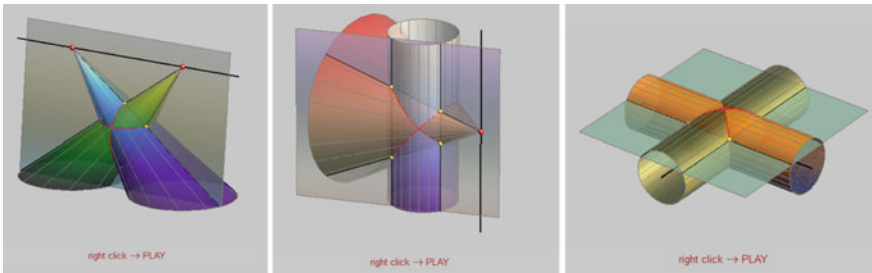


Fig. 5 The construction of the intersection curves of cones and cylinders visualized by *Mathematica* animations

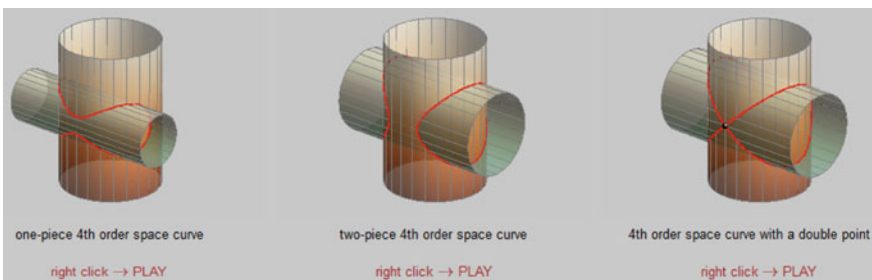


Fig. 6 The visualization of the intersections of two cylinders by using *Mathematica* animations

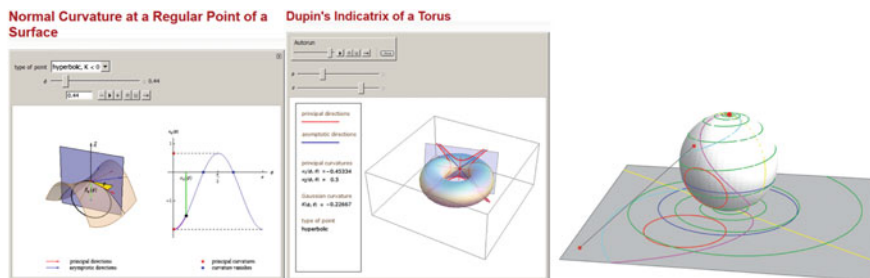


Fig. 7 The illustrations of three exceptional students' seminars [2, 4, 6]

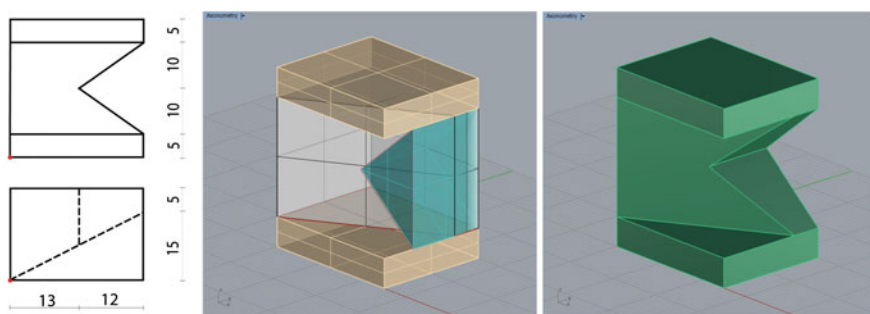


Fig. 8 Two principal views, a *Rhino* construction and the axonometric view of a model

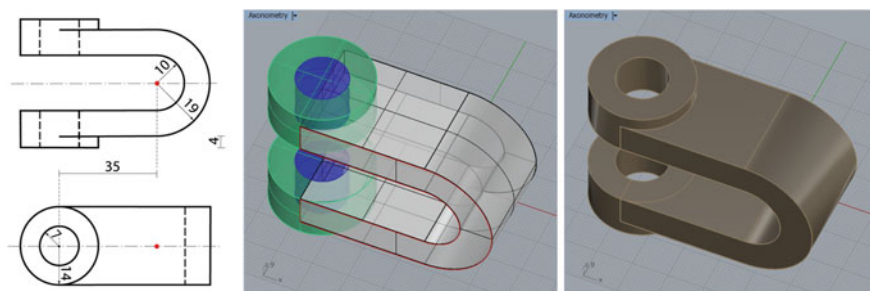


Fig. 9 Two principal views, a *Rhino* construction and the axonometric view of a model containing the cylindrical parts

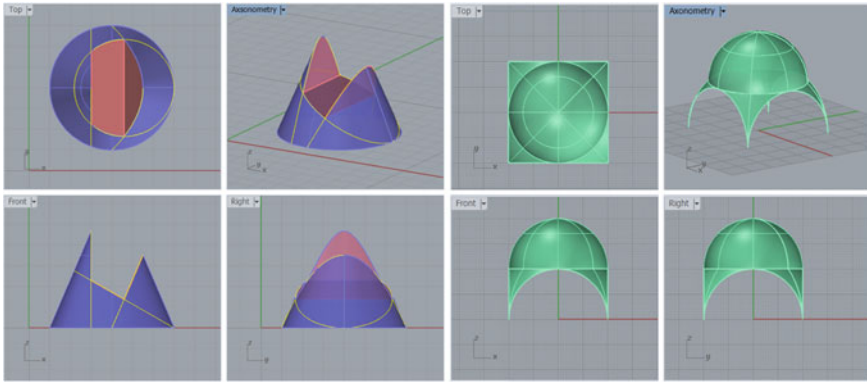


Fig. 10 Two examples of the intersection of surfaces with the planes given in three principal views and an axonometric view: the cone intersected by three planes (*left-hand side*), the Byzantine dome - sphere intersected by five planes (*right-hand side*)

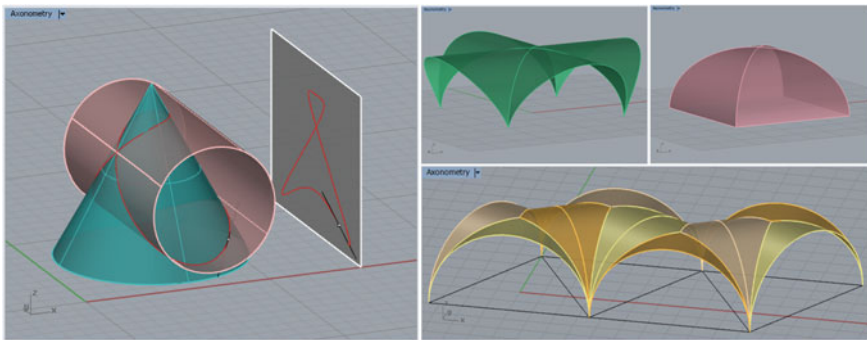


Fig. 11 Four examples of the intersection curves of surfaces

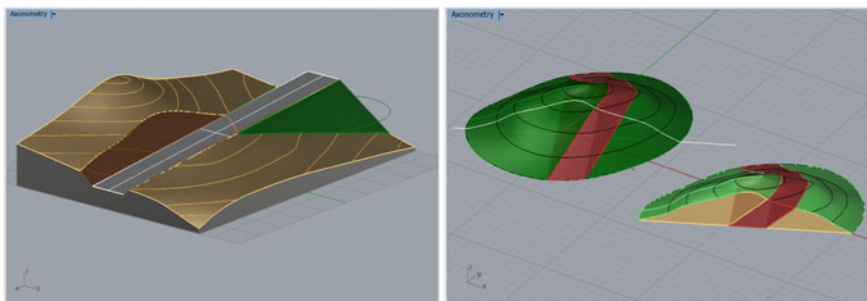


Fig. 12 Two examples of the topographic surfaces modeling: the terrain with a road (*left-hand side*) and the layer (*right-hand side*)

3 Examples

In this section we present the repository of educational materials by showing the examples of using three aforementioned programs, *GeoGebra*, *Mathematica* and *Rhinoceros*, for different topics in geometry.

To create educational materials related to planar figures and transformations we used *GeoGebra*. This dynamic geometry software, written in *Java*, enables us to design interactive network files that a teacher can use during lectures but, although our students solve their tasks by hand drawing, these interactive educational material is a very good support for their home learning.

Mathematica is a program which is used as a numerical and symbolical calculator, computer language, the system for visualization of functions and data, the platform for designing packages for specific applications and creating interactive documents with texts, animations, sounds, etc. As such, it is not the most suitable program for teaching and learning constructive geometry that is connected with CAD programs. But, due to its great graphics possibilities, the largest number of figures and animations that we included in the educational material for the lectures on descriptive geometry is produced with this program.

On the other hand, *Mathematica* is an ideal program for all topics of the differential geometry. Thus, in the case of *Differential Geometry* course at the Faculty of Geodesy the complete textbook, that is partly made in the framework of this project, is produced by using *Mathematica*. Some examples of the earlier use of this program at the Faculty of Civil Engineering is given in [3].

The program *Rhinoceros* can create, edit, analyze, and translate NURBS curves, surfaces and solids in Windows, and therefore, it is very suitable for teaching descriptive geometry. One of the reasons for choosing *Rhinoceros* was a relatively low cost of the educational lab licence and the free trial versions available for students' downloads. The other reason was good experience of colleagues from the University of Innsbruck.

One of very important topics of descriptive geometry is the axonometric projection. After the axonometry had been introduced to students, they had to make a hand-drawing of an object given by two (or three) principal views, but they also had to create a model of the object by using *Rhinoceros*. The commands for the solid modeling and the axonometric view in *Rhinoceros* were presented to the students in seven videos.

Rhinoceros was also integrated in the topics traditionally treated by two orthogonal projection (the intersection of a surface and a plane, the intersection of two surfaces) and topics treated by the projection with elevations (the topographic surfaces, the terrains with the roads, layers).

Last academic year at the Faculty of Civil Engineering fifth year students (the second year students of the graduate study) had the opportunity to attend the optional course *Perspective*. Those students were not familiar with *Rhinoceros* 3D modeling. Therefore, after a successful completion of the first part of the course where basic properties of perspective were introduced, the students first had to learn

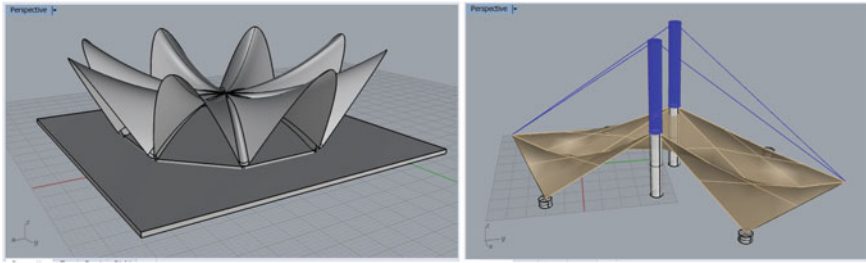


Fig. 13 Students' constructions related to a hyperbolic paraboloid. (L. Ivančić and M. Anđić)

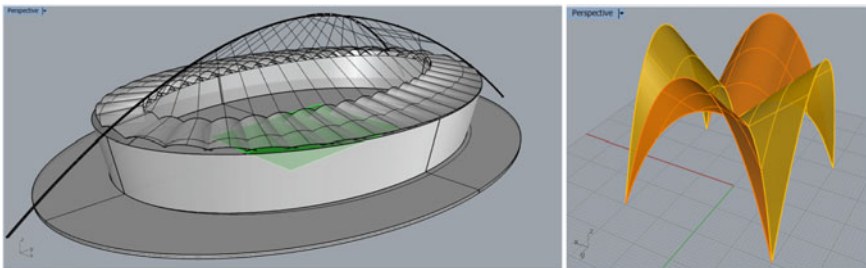


Fig. 14 Students' constructions related to a 3rd order paraboloid conoid. (M. Anđić and I. Škaro)

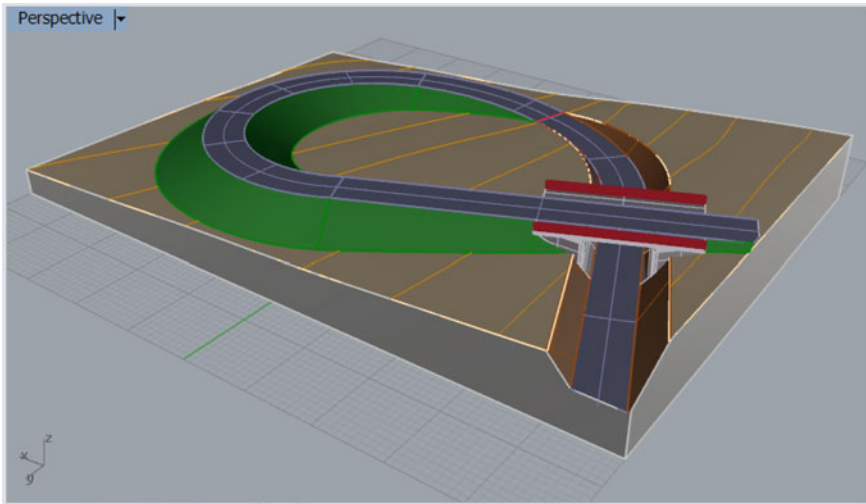


Fig. 15 Student's construction related to a road on terrain. (M. Anđić)

how to use this program and then they had to apply their knowledge to modeling ruled surfaces and roads on terrains. Some of the students' constructions are presented in Figs. 13, 14 and 15.

References

1. Beban Brkić, J., Gorjanc, S., Tutek, Ž.: New Challenge for Developers of E-infrastructure. In: Proceedings of 15th ICGG International Conference on Geometry and Graphics, Montreal, 2012
2. Car, V., Dragun, D., Beban-Brkić, J.: Multimedia Concept in Visualization of the Polar Stereographic Projection. *KoG*, No. 12, 2009., 55–62 (in Croatian)
3. Gorjanc, S.: Some Examples of Using Mathematica and webMathematica in Teaching Geometry. *J. Geom. Graph.* **8**(2), 243–253 (2004)
4. “Dupin’s Indicatrix of a Torus” from the Wolfram Demonstrations Project. In: Gorjanc, S., Štambuk, D. (eds.). <http://demonstrations.wolfram.com/DupinsIndicatrixOfATorus/>
5. Introducing 3D Modeling into Geometry Education at Technical Colleges. <http://www.grad.hr/geomteh3d/>
6. “Normal Curvature at a Regular Point of a Surface” from the Wolfram Demonstrations Project. Štambuk, D. (ed.) (University of Zagreb), Gorjanc, S. <http://demonstrations.wolfram.com/NormalCurvatureAtARegularPointOfASurface/>
7. Resolution on Forms of University Education According to Application Level of E-learning Technology (in Croatian). http://www.unizg.hr/fileadmin/rektorat/Studiji_studiranje/Studiji/e-ucenje/UNIZG_oblici_svnastave_razine_e_ucenja_20091222s.pdf. Accessed 03/01/2014
8. University of Zagreb E-learning Strategy 2007–2010. http://www.unizg.hr/fileadmin/rektorat/dokumenti/eucenje_strategija/University_of_Zagreb-E-learning_strategy.pdf. Accessed 03/01/2014