Application of 3D animation principles and tools in geometrical education

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Abstract

Geometrical education using 3D animation principles and tools represents a new methodology approach and its final result is presented on new way, as multimedia tool. The originality of the paper is based on interdisciplinary approach and use of new technologies. The method derived from the overlap of multiple disciplines such as architecture, structural systems, descriptive geometry, computer animation and programming. Teamwork is comprised of different disciplines since the authors working in different domains of architectural studies. This paper is presented as a visual dynamic educational tool for students of technical and applied arts faculties. The aim is to simplify the perception of geometric forms and the process of their construction. The results leads to the production of geometry with complex topology and could be more developed. So, the results are multilayered, and are the solid basis for further scientific research and further development in practice. The geometrical education target group is the students of the technical and art faculties. It is necessary to emphasize that this work is the beginning of our further scientific research papers in different areas due to an interdisciplinary approach. These areas are: geometrical education, pedagogical theory and psychological aspects of teaching and experimental design in architecture. Aspects and research results presented in this paper are: the basic structure of multimedia learning aid, production methodology, and the final application in education.

Key words: Geometrical education, experimental design, computer animation

1. Introduction

Perception and construction of geometrical space is the most essential needs in the education of both art and engineering students, especially the technical and technological filed. Geometrical education includes spatial perception and visualization of spatial structures. Development of dynamic and interactive animation programs for the study of geometry overcomes the perception problem and improves the development of spatial visualization ability (Figure 1).

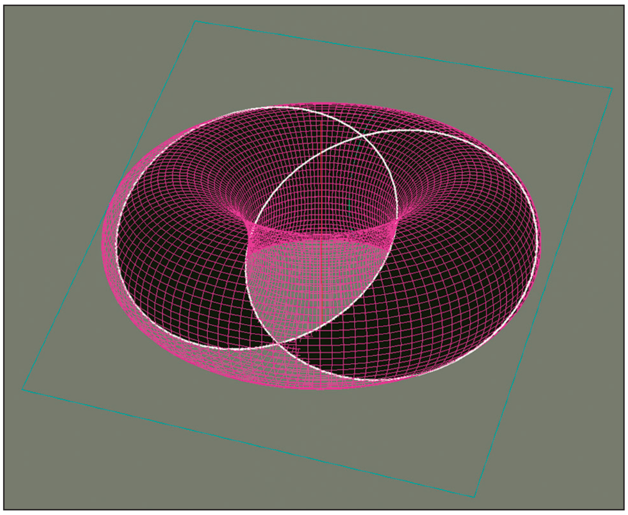

Figure 1. Frame from the 3D animation from multimedia DVD that shows the structure of rotation torus, and the resulting intersection curve with the plane. The figure shows the case when the resulting intersection curves are Villarceau's circles

This paper is based on the two hypotheses. The first one is that the use of multimedia tools in educations of descriptive geometry is new standard in geometry education. The second one is that the application of virtual technology in education through experimental design could be used for practicing more complicated operations and for analyzing the different forms, their arrangement as well as their relationship within the space. By elaboration of this hypothesis we confirmed the hypothesis and we emphasize that this work is important research in the field of application of methodological innovation in the area of space geometry and computer animations with the focus on geometry education in domain of visualization and experimental design. The geometrical education includes the geometry in the plane and space geometry. Engineering disciplines provide visualization training, which includes geometry, perception and design of geometrical space. Space perception involves the acquisition of knowledge dealing with spatial relations, classification and ranking of spatial relations, transformation and rotation relations between the parts and a whole of space. The graphical representation includes sketching, graphic design, static and dynamic presentation. By meeting the expected results is anticipated a move towards more simple and more effective educational process. The applicability of dynamic 3D geometry in education provides improvement of spatial ability, ease of application, pedagogical stimuli for users in terms of encouragement for the further geometry exploration. The dynamic component enables users to develop the spatial ability. The proposed form of educational environments is a new potential for the study of geometry.

2. The perception in education

For the humans, the vision is the most important sense. All sensory sensations inherent to physiology of the humans are more than 70% belong to the field of visual perception or the sense of vision. A special feature of visual perception is the capacity to grasp the three-dimensional space [1]. The comprehension ability of three-dimensional space means to estimate the relative distances between objects as well as the inner sense of form shape, i.e. the third dimension of space (Figure 2) [2].

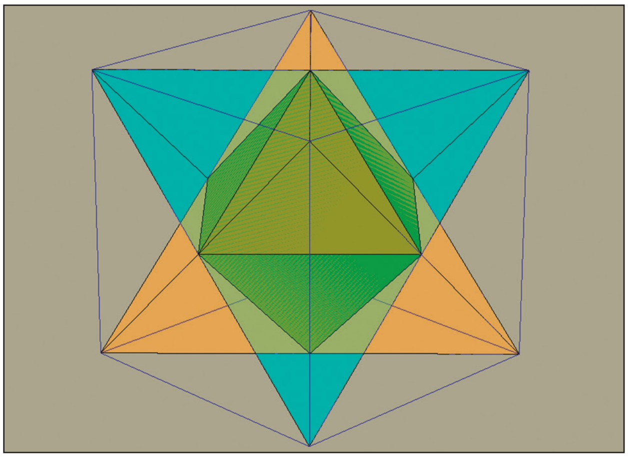

Figure 2. Frame from 3D animation multimedia learning DVD showing the process of constructing tetrahedrons inscribed into a cube, which results in octahedron by mutual intersection.

The main reason why the work was presented as short-form animations with concise text explanations is because of the aforementioned facts related to the perception in the education.

Geometrical education

Geometrical education enables development of the ability of spatial representation, perception and understanding of space. Drawing is a means but not the goal of geometrical education. Geometrical education in the scientific hierarchy is placed in the field of mathematics, as well as with the field of architecture, mechanical engineering and engineering graphics. Geometrical education enables perception of space abilities training and that's why is definitely important for all engineers, physicists, and artists as well as natural sciences students [3].

Pedagogical theory - constructivist theory

This paper is based on constructivist theory. Citation: "Constructivism is a cognitive theory that emphasizes that learners construct new knowledge by rearranging and refining their existing knowledge."[4]. Constructivist theory provides a valid and reliable basis for a theory of learning in a virtual environment. As constructivism emphasizes, learning process is carried out when students are able to build conceptual models that are in accordance with what they already understand and with new content [5].

With the aim to provide the successful implementation of a new experience of learning the flexible learning path must be provided. One possibility is to integrate known types of information and educational support different from the 3D presentation (such as audio and text comments, images, etc.). Another option is to carefully define the specific tasks for the students through interaction with the teacher. Numerous authors (like Professor Hannes Kauffmann in his PhD dissertation) suggest that using different models of learning in a virtual environment from those who are guided by teachers to autodidactic learning models [6].

Finally, the virtual environment can be adapted to a variety of approaches, from individual learning to the performance of various styles [7]. Commitment to constructivist position includes a basic principle that knowledge is not transmitted directly from teacher to student, but is actively completed by students. Learning is considered as an active process in which students "construct" their knowledge by testing ideas and approaches based on their prior knowledge and experience and applying them to the new situation, and integrating the new knowledge gained with previously existing intellectual constructs. This is supported by appropriate learning activities, engaging, involving problem solving and critical thinking. Relying on the constructivist theory, we suggest the use of 3D animation in geometrical education and we consider that it is fully compatible with constructivist pedagogical theory.

The psychological aspects that are mentioned on this paper are related to cognition that is spatial cognition. In addition, we discussed on possible aspects of spatial ability that could affect by the application of virtual technology in geometrical education. Regarding spatial intelligence Durlach et al. give a very good overview of the work and results achieved in the field of improving spatial abilities using virtual technology but mainly identify the necessary need for a comprehensive future research in this area [8]. When discussing the psychological aspects of perception of space, a wide range of discussions on how human processes - handles simple spatial objects to the study the orientation of people in the real environment. We are working with sub dimension of spatial cognition that is related to the impact of training in a virtual environment as well as the basic principles of training of spatial abilities (Figure 3).

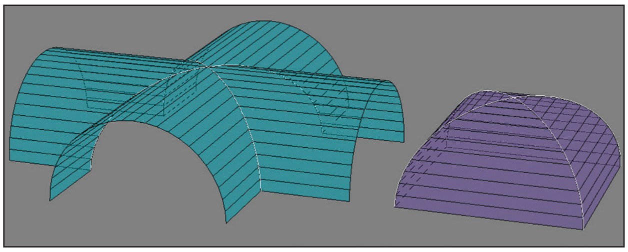

Figure 3. The results of mutual intersection of two half cylinder is especially important both for education and training appropriate for spatial abilities. The frame is taken from 3D animation multimedia learning DVD

Digital technologies and the hybrid approach

The use of digital technology in itself includes an interdisciplinary approach. For example, if you look at the area of digital art, we see constant changes in the categorization of digital art. On the example of digital art festival in Linz, one of the largest and most important of this type. Categorization is affected with submitted artworks themselves, which leads us to the constantly changing art category types in digital arts. Since 2007. year has been introduced a new category of hybrid art, in addition to previous categories of computer animation, interactive art, digital communities and digital music. The primary aim of introducing the hybrid category of art is, as stated, expanding the borders of existing categories of the festival: Hybrid art is category specifically dedicated to today's hybrid and transdisciplinary projects and approaches to projects and media arts. The focus is on fusion of different media and genres into new forms of artistic expression as well as transcending the boundaries between art and education, the arts and research, art and social and political activism, art and science. The hybrid category of art are: the autonomous installations, autonomous sculptures, performances and live performances, media architecture, media intervention in public space, mechatronics / kinetic art / robotics, artificial life, transgenic art, software art and generative art. It is possible that in future some of these listed topics of digital art will be a separate category for itself. This open approach allows changes in the art categorization and digital art definition itself. [9]

Dynamic 2D geometry software

The beginning of dynamic geometrical education went through the application of 2D geometry software. Since computers can record the way we construct geometrical objects, the software is able to do it again after changes to the structure of certain parameters. This is the key concept of dynamic geometry: select the item which is then changed position and currently you can see changes in the structure. This ability of movement is fundamentally improvement regard to the drawing on the paper or static CAD models. The comprehensive work on the dynamic geometry is explained by a Kortenkamp in "Foundation of Dynamic Geometry" [10]. Kortenkamp explained the importance for the educational purposes of the fact that one can explore the behavior by moving the same geometrical structure. We can observe which parts of a construction change and which the same, unchanged remain. It is made much more insight into the actual construction and general geometry, if we can experience what happens when you start moving that construction. More sophisticated software provides yet another, further understanding and explanation supporting the location as well as the traces of the movement of the object that is dynamically adjusted. The first software packages for dynamic geometry dating from 1988. are Cabri Geometrie and Geometer's Sketchpad from 1989. Since then it is very much done on the introduction of dynamic geometry software in education. Today there is a very large number of software for dynamic geometry. The most popular are Cinderella after Euclid and aforementioned Geometer's Sketchpad as well as the Cabri Geometre. All these software's work only 2D geometry.

Dynamic 3D geometric software

Virtual technologies are easily accessible tool for visualization. With the development of new technologies, they have become common tool for educating, initiating the development of dynamic geometry suitable for training and experimental design [11]. The specific contribution is in the education by working with 3D animation for students of art and engineering field of technical - technological group of students. We emphasize the importance of dealing with design dynamically-generated form. In the history of CAD, there have been two revolutions, so to say. First when converted from drawing on the paper to draw on the computer, the following is the result of software development tools that simplify the design process and led to a design process and a simplified way of thinking, from "the paper" transferred "to think in the software" (for example [12]. CAD applications have many similarities with the dynamic geometry software. This may be used in prototype construction that can be quickly adjusted. Also could be used for quickly and easily construction of a simple model as a start from the further parametric design and prototype production. Not only this situation but many others have similar problems as in dynamic 3D software. Many CAD applications support precise construction. Among the best known are: Catia, Rhinocerous, Autodesk Mechanical Desktop™, SolidWorks™, as well as the many others. Programs for digital 3D animation resulting from CAD programs to draw precisely, with the key difference is that their product output is IMAGE – animation, which is not a prototype. For this reason, the emphasis is on ease objects manipulation in 3D space, and simplified controls for construction, which are especially important for modeling the so-called organic models such as the human figure. This was the main reason why the animation used for 3D multimedia learning DVD is done in this kind of software. The most famous programs for 3D computer character animation are: Autodesk Softimage, Autodesk Maya, Autodesk 3ds Max, Cinema 4D, Blender and others. Considering that our work relates to the 3D animation application in the geometrical education, the areas of 3D animation follows [13].

Areas of 3D animation

There are several areas of 3D animation: character animation, parametric animation (visualization based on mathematical functions), medical and other scientific visualization, dynamic simulation based on the laws of physics (fluids, cloth, fur, the interaction of solid bodies, etc.), architectural visualization and presentation in industrial design [13].

The application of virtual technology (VT)

Virtual geometry and importance of topology

In analyzing the geometry of 3D models for animation, we have to analyze the topology. Topology refers to the geometric characteristics of mesh of the 3D objects, the number of points (vertex / vertices) and the way how they are connected. Topology is important when smoothing algorithm on the polygonal objects (subdivision) is applied. The most demanding is the modeling of the objects that could be deformed (animated). Then the topology should fulfill one another important requirement that is to have the regular deformations. (Figure 4).

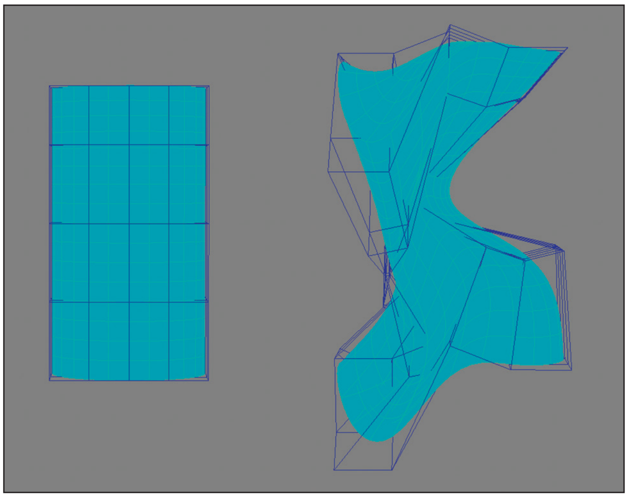

Figure 4. The example of free-form experimental design using 3D animation deformers. The frame is from 3D animation multimedia learning DVD

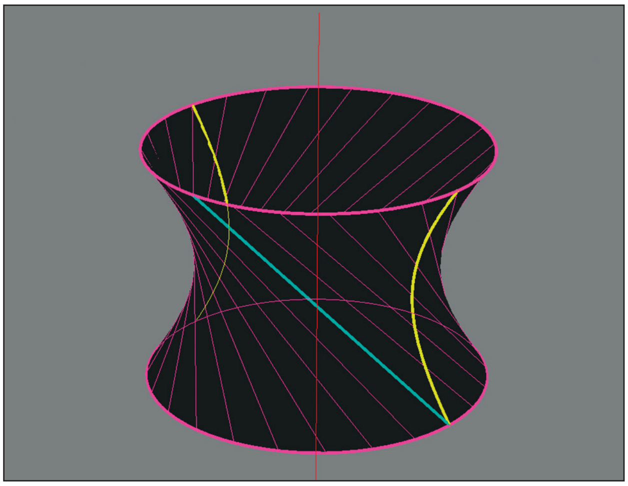

Figure 5. Example of construction of rotational hyperboloid, rotating ruled surface. The construction methods are rotation the one line and the one sheet of of a hyperbola around its vertical axis. The frame is from 3D animation multimedia learning DVD

Implementation of virtual technology (VT)

Implementation of virtual technology refers to the use for the dynamic education in areas that are in our opinion the most suitable for this method. Dynamic geometrical education tool was made by live recording of whole process of construction the geometry in 3D software. After that, this animation is subtitled. All process was done in the Studio for digital 3D animation at the Faculty of Architecture, University of Belgrade. Software for 3D animation – Autodesk Softimage was donated by US AID to Faculty of Architecture, University of Belgrade in 2007.

3. Results and discussion

The resulting multimedia DVD learning tool consist of 16 animations, 5 minutes duration in average. Following geometrical areas are processed:

1. Platonic solids: cube, tetrahedron, octahedron, dodecahedron and icosahedron
2. Ruled surface: conoid, rotational hyperboloid, helicoid and hyperbolic paraboloid
3. The surface of revolution: the torus
4. Mutual intersection: conic sections, cone and cylinder, sphere and cylinder and two half-cylinder
5. Experimental design (freeform): generating a surface with the two profiles as guidelines, generating free form using lattice deformers and generate free-form by the duplicating along curves [14].

Aforementioned areas were chosen because the students have problems to see the geometry in 3D space. Platonic solids are treated as the basis for generating space structures and constructive systems [15]. Ruled surfaces are the easiest to generating by using virtual tools for 3D animation while heavy understanding in the 2D image (Figure 5). Intersections and the resulting intersection curves as well as intersecting surfaces are particularly delicate. Their perception is the easiest in these kinds of applications (Figure 6). The process of making or working on these animations using principles of geometry while adapted to the realization of in 3D software. The point is that the students besides the easy perception and learning also could enable themselves to repeat the same process and to continue to explore. The work is specifically included working together of all authors.

The work was finally presented as a short animated form. The whole process is directly recorded in of 3D software, and every animation has additional text that follows and explains the procedure and gives the basic definitions. In order to demonstrate the potential of 3D geometry education, we have done examples which are different in difficulty but all belong to the geometric area of the university educational levels. The geometric content is very diverse in terms of their position in curriculum. Variety of selected areas has shown how the different fields may be processed in the virtual environment.

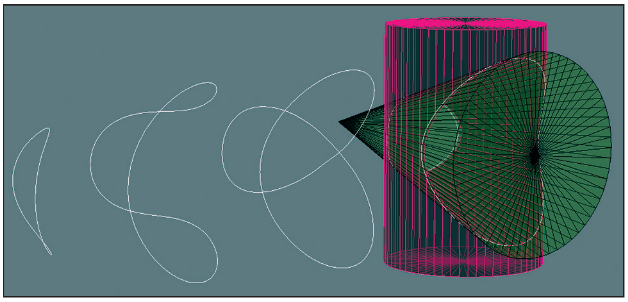

Figure 6. The example of Boolean operations in intersection of cone and cylinder. Different types of crossing curves are the result of cone or cylinder animation. The frame is from 3D animation multimedia learning DVD

The animations from multimedia DVD presents: the application of Boolean operations (subtraction, union, intersection) in mutual relation of solids, the study of revolved surfaces and their geometrical properties; the study of curves and surfaces 2nd sort (intersection curves of two cylinders); regular polyhedra and their relationships; ruled surfaces and surfaces of revolution; free form. We wanted to to demonstrate which areas are most suitable for this type of learning and pedagogical methods that could be used. We aim to find directions for the geometrical content as well as the geometrical principles that could enable understanding and learning in a virtual environment.

Geometrical education by using 3D animation supported different learning tools for students from auto didactical to guide by teachers as well as more autonomous way of learning. According to our opinion the interpretation of spatial constructions in the plane requires a lot of spatial thinking and understanding of spatial problems. Using tools that we propose to use spatial geometrical ideas could be tested, developed and realized in a short time. Particular significance in educational sense is that it is possible, in completely new examples and applications, to perform the implementation of 2D geometry in a dynamic 3D space. We consider this as a very perspective and inspirative base of our current and future work. We would like to stress the possibility of further research in construction of different geometrical problems, using available applications for 3D animation in geometrical education.

4. Conclusions and directions for future research

We are witnessing the rapid development of technological aids. At the intersection of reality and computer-generated information a new world is developing that affects all aspects of life. Digital technologies have since the mid 90-is moved from the laboratory into people's lives, and become more available to a wide range of users. Today virtual technologies represent the standard in education [16]. New instruments allow students, teachers, artists, researchers, engineers, designers, etc. empowerment in all field of work, from education to practice.

Virtual technology in the function of geometry learning tools offers new and fascinating possibilities. Students and teachers can explore the most diverse theoretical and practical problems with the aim of understanding the dynamic and complex spatial relationships. Users of virtual technology research communicate and understand the spatial problems in new ways. It is possible to work interactively with objects in a simulated environment and to teach through movement, interaction and immediate response [17]. These capabilities offer a new way of communication between teachers and students which were not possible at conventional ways of teaching. The use of virtual technology in the teaching related to the geometrical education improves and greatly speeds up explanations of teachers intentions [18].

Experience in the use of virtual technology in the learning process demonstrates significant progress in the perception of huge possibilities working with each model. Today's conventional hardware and software packages allow the use of virtual technology quite simple. This enables the exchange of theoretical and practical knowledge among participants in the distanced locations which is one, between many of observed advantages of digital multimedia education [19].

Virtual technologies are good platform for teamwork. Teachers can collaborate with students using interactive media, which includes design and communication at a much more direct way than simple file sharing. All participants showed a higher level of interaction and the working possibility are multiple [20]. Communication is enhanced through a media that allows the joint participation in the processes of thinking, creating and understanding. Virtual technologies demonstrate a possibility of establishing a unique combination of collaboration and communication of interactive teaching process that is transparent and direct [21]. Users of virtual systems have tremendous opportunities to explore spatial relationships and geometrical characteristics of the topics being processed in this paper [22].

Dynamic educational experience in a virtual environment is especially important. Dynamic geometry education achieved much higher insight into the actual structure and construction, because through the movement directly experientially we learn about the changes in the construction of the structure. Animation is a new dimension in geometrical education. Using virtual systems is enabled more complex communication and understanding of spatial relationships of geometric area, which is processed. This innovative approach leads to new form of design. The usage of tools for 3D animation open up new perception of the tangible existence of geometric forms (all in motion, nothing is static) as well as the sensational dynamic manipulation of the geometry.

The original contribution of this paper is in the implementation of multiple disciplines, and this interdisciplinary hybrid approach, overlapped several disciplines such as architecture, descriptive geometry, computer animation and programming. As the authors themselves are educated in different disciplines: architecture, descriptive geometry, digital animation, and constructive system, the result through teamwork is in implementing through the education of students in technical and art faculties as well as the scientific research work in the design of dynamically generated forms.

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