3D modeling in the study of the basics of computer graphics

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Abstract. Teaching the basics of computer graphics is included in the process of training bachelors of different directions. Knowledge of the theoretical foundations of computer graphics is important for future successful professional activity. There are methods of increasing the efficiency of their study through the implementation of practical tasks in this article. Students are interested in performing tasks related to 3D modeling. They are proposed to develop three-dimensional interactive models for use in the study of other disciplines. Students develop independence, creative thinking, ability to plan their activities, when they create such models.

Computer graphics are used in many areas of human activity. The study of its basics is included in the process of training bachelors of most directions. During studying disciplines related to computer graphics students develop competences that provide the development of spatial awareness and constructive-geometric thinking. Student forms abilities to analyze and synthesize three-dimensional configurations on the basis of graphic models. Programs of computer graphics courses contain the basics of working with 3D graphics editors such as Autodesk 3ds Max, AutoCAD, COMPAS-3D, Blender, etc. The knowledge acquired by students in the field of creation, processing and output of graphic images, as well as the skills of using computer-aided design systems help to improve the level of readiness for professional activity. For example, using mixed simulation environments in training future engineers [1] or the introduction of 3D modeling technologies in the educational activities of students [2].

Modern 3D graphics editors allow to perform realistic models and animations. They are used in creating virtual laboratories and simulators [3-4]. Such applications help in the formation of professional competences of students [5].

Courses for studying the basics of computer and engineering graphics are widely presented on platforms of online education [6]. Platform “Open education” offers courses “Engineering and Computer Graphics”, “3D Modeling”, “3D Imaging” and others. It is supposed viewing video lectures, working in 3ds Max and AutoCAD editors. Three-dimensional modeling, engineering graphics, principles of work with 3ds Max, AutoCAD, COMPAS-3D, Blender can be studied on the educational
platform Stepic. Coursera and edX platforms offer to study the basics of 3D modeling and engineering graphics by learning Autodesk Fusion 360, Blender and more.

As a result of studying the bachelor’s program (“Information systems and technologies”), general professional competences should be formed. Including: “To have ability to develop algorithms and programs suitable for practical application in the field of information systems and technologies”, “To have ability to apply natural science and general engineering knowledge, methods of mathematical analysis and modeling, theoretical and experimental research in professional activity”. A program of preparation of bachelors includes “Computer graphics and design” discipline, which is a discipline of choice. A large number of students choose this discipline every year. Online course “Computer Graphics and Design”, which is used during the study of this discipline and introduces the basics of computer graphics and theoretical provisions of 3D modeling, was created and posted on https://edu.kpfu.ru/. It is provided to perform laboratory work in 3ds Max and Blender editors.

Every year since 2016, a survey of students is conducted. Since applicants begin to be interested in graphic editors at school, they are suggested to evaluate their progress. In 2016 the survey was participated by 42 fourth-year students. The answers were as follows: Before studying the course “Computer Graphics and Design” 19 students (45.2%) did not know the principles of working with 3ds Max, 18 students (42.9%) knew the basics of discipline, 5 students (11.9%) knew the discipline at good and excellent level. After studying the course “Computer Graphics and Design” 7 students (16.7%) know the basics of working with 3ds Max, 35 students (83.3%) know at good and excellent level.

The results of a survey were as follows. Only 24% of students answered “Yes” the question “Do you think you need to further study the use of graphic libraries, such as OpenTK?”’. Some of the students are already familiar with libraries of this type and use them during performing tasks of other disciplines. There were no positive answers to the question “Do you think it is necessary to study more theoretical provisions?”’. The results of tests also showed that the level of knowledge of the basic theoretical provisions sharply decreases after the completion of the course. Meanwhile, graduates with a degree in "Information technologies and systems" need to know the theoretical foundations of computer graphics, formulas of computer geometry. Since in their future professional activity it is planned not only to use ready-made applications, but also software implementation of algorithms, including solving problems related to computer geometry and graphics. Students noted that they are motivated to study the theory deeply when they realize that these facts and provisions will be necessary in future professional activity. Therefore, it was decided to link the study of theoretical provisions with specific tasks for laboratory work. Practical tasks were changed in such a way that during performing a task a student had to repeat the theoretical material and to see the result in practice.

For example, after studying the topic “Ray tracing”, it is suggested to check the refractive and reflective parameters. Figure 1 shows the result of modeling a scene in 3ds Max with different trace depths.

![Figure 1. Modeling a scene in 3ds Max with different trace depths.](image)
During performing this task, the basics of ray tracing are understood. A more complex task, in the course of which it is necessary to study the influence of parameters of reflection and refraction on the quality of the obtained image, is proposed.

Three-dimensional models are used in the study of different disciplines and for different age categories. For example, a learning experiment with gear ring modeling [7] or models are used in landscape design training and urbanization project development [8]. The next direction of students' activity is the development of models for use in the teaching of other students. For instance, it is offered to perform a training model during studying the embedded scripting language MAXScript of the 3ds Max three-dimensional modeling package. The script simulates the location of molecules in the gaseous state of substance (figure 2).

```plaintext
for i=1 to 15 do ( 
    a=random -50 50; b=random -50 50; c=random 1 100; d=random -90 90
    s=sphere (); s.radius=5; s.wirecolor= (color 0 0 255); s.pos= [a, b, c]
    s1=sphere (); s1.wirecolor= (color 133 133 250); s1.radius=3; s1.pos= [3+a,3.2+b,0+c]; s1.pivot= [a, b, c]; s1.rotation= (quat d [a, b, c])
    s2=sphere (); s2.wirecolor= (color 133 133 250); s2.radius=3; s2.pos= [3+a, -3.2+b,0+c]); s2.pivot= [a, b, c]; s2.rotation= (quat d [a, b, c])
```

Figure 2. The result of performance a script simulating the location of molecules in the gaseous state of a substance.

To perform such a model, the student must have the knowledge of physics and chemistry, understand the principles of operation with scripts, think over the design.

Figure 3 presents the student's work, where he created a script, which simulated the flight of the ball on a fixed trajectory. In this case, the user can change the speed and initial coordinates of the ball and explore the flight trajectory. The planets of the solar system are simulated on figure 5. Their location and movement can be viewed from different points. In addition, students are given maximum freedom to choose the algorithm, logic of the training model, design styles, etc.

Figure 3. The result of modeling the flight of the ball along the given trajectory.

Figure 4. The results of modeling the planets of the solar system.
A survey conducted in 2019 showed that students are interested in such tasks. They noted that the tasks increase motivation, make to study the theoretical foundations more thoroughly. During the classes, the models were discussed, classmates noted the positive and negative aspects of the completed task. Students should perform models which are intuitive for users. This requirement increases the level of readiness for professional activity, as developers of information systems need to be able to work with requirements of users.

The number of students using 3D models in the course of graduate qualification works has also increased.

Control tests for checking the level of theoretical knowledge of students were carried out during the course and after the end of the course. The results are presented in table 1.

|                | During studying the discipline in 2016 | During studying the discipline in 2016 | During studying the discipline in 2019 | During studying the discipline in 2019 |
|----------------|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|
| «5»            | 14                                    | 4                                     | 14                                    | 13                                    |
| «4»            | 10                                    | 10                                    | 8                                     | 6                                     |
| «3»            | 10                                    | 12                                    | 9                                     | 10                                    |
| «2»            | 8                                     | 16                                    | 1                                     | 3                                     |

The number of students, who demonstrated knowledge at good to excellent levels in 2016, decreased from 24 in semester to 14 after semester (42%). In 2019, during the course 22 students responded to “good” and “excellent”, and after the course 19 students did (a decrease of 14%).

Thus, the use of active tasks contributes to the good consolidation of theoretical knowledge. Students demonstrate a high level of retained knowledge in the discipline. Such practical tasks help to develop creative abilities of students, stimulate independence in the planning of educational activities. Execution of tasks, where students are not given a complete action plan and made an opportunity to build their own logic, develops the ability to find solutions in non-standard situations.

In 2019, the material of lectures on the discipline “Computer Graphics and Design” was provided as part of a distance course. The problem points were discussed in the consultations. Students consider that this form of work is convenient. Submission of theoretical material and subsequent consolidation in practice minimized the number of topics, which raise student questions. The next stage of work is planned to develop interactive tasks which will be include in the distance course.

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