Development of Technique for Generating Adaptive Visualization of Three-dimensional Objects in the Cloud Educational Environment*

Vladimir Shardakov[1 [0000-0001-6151-6236]], Denis Parfenov[1 [0000-0002-1146-1270]], Irina Bolodurina[1 [0000-0003-0096-2587]], Igor Parfenov[1 [0000-0003-1671-3921]], and Veronika Zaporozhko[1 [0000-0002-2193-9389]]

Orenburg State University, Orenburg, Russia
{prmat,fdot_info,zaporozhko_vv}@mail.osu.ru

Abstract. In this study, we consider the technology of cloud virtual reality for the educational platform through the formation of the three-dimensional scene to prepare students for distance learning. Such advanced learning technologies and learning systems are constantly in demand and are in the spotlight. In this work, three-dimensional models were created. It was integrated into the real scene for providing the 360-degree view of this scene. The study conducted the analysis of the developed 3D models of the prototype module of adaptive visualization of three-dimensional objects for the virtual educational environment which constructed on the cloud platform. The study showed a change in the dependence of the minimum number of frames per second on the screen resolution, which is more often used to display the graphical component. We prepared the structural model of the cloud infrastructure for processing data and visualization of three-dimensional objects. In the framework of experimental research shows the results work of the prototype module adaptive visualization of three-dimensional objects for the cloud educational platform.

Keywords: Multicloud platforms · Virtual reality · Virtual tour · 3D visualization · 3D models

1 Introduction

High-quality visualization of large areas is the main condition for the creation of computer graphics in the different information systems, such as geographic information systems (GIS), various simulators, landscape editors, etc. An important role in the formation of the photorealistic image of the landscape is

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played by textures imposed on the polygon model. Let us single out a number of features characteristic of such textures. First, they must have a high resolution. This needs when the camera is close to the surface of the landscape. The closer the camera the more visible the details. Secondly, from a great height, the repeatability of the image should not be noticeable, if the same type of texture is repeated many times over the entire surface [6, 8].

Modern technologies allow to move to a new level of training through the use of three-dimensional interactive virtual systems that are most adequate to the real world [1].

The development of 3D training systems can be considered a multi-criteria optimization problem, the solution of which should ensure the adequacy of the virtual environment and the speed of computing processes sufficient for the formation of images in real time [11, 12, 14].

2 Related Work

To solve the problem of photorealistic texture relief in recent years, many methods have been proposed. In some works [1, 2], the whole scene is represented by a single image.

The approach [1], is quadra drive, each node of which corresponds to the texture that contains the rectangular area of the original image and filtered in the full MIP pyramid. Textures that lie higher in the tree cover a larger area but contain less detail. At runtime, depending on the observation settings, the desired level of texture detail and the corresponding tree node are selected to visualize different parts of the surface. Missing sections loaded from disk, the junk is unloaded from memory.

In [2], the image is divided into rectangular areas of the same size, each of which can be loaded into the video memory of the graphics card. Approaches that use a unique image provide a high variety of images and avoid its repetition. However, to maintain acceptable visual quality when approaching the surface, the texture must have a very high resolution, and as a result, a very large size, which can easily exceed the capacity of the computer's memory. Therefore, such approaches use complex algorithms of dynamic loading of the required image areas and are associated with high memory costs.

Scientists from the Taiwan University proposed a navigation system in virtual reality, which automatically generates animation to objects using algorithms borrowed from robotics. This system is adapted to one particular building, and the final scene image is low polygonal, which significantly affects its quality [3].

G. Snook in his work proposes to use a linear combination of colors 4 textures with weights, which are contained in the components of color and control, texture. This method is effective but does not give a high realism of the image, because only 4 materials are used [4].

Some other approaches suggest calculating color based on surface characteristics. For example, in the work of a team of scientists led by C. Dachsbacher texture is generated procedurally on the GPU based on the height and slope of the terrain at a given point. However, this approach cannot provide high image quality when approaching the surface at close range due to limited texture resolution [5].

Therefore, the development of 3D training systems can be considered a multicriteria optimization problem, the solution of which should ensure the adequacy of the virtual environment and the speed of computing processes sufficient for the formation of images in real time.

3 The Architecture of the Virtual Learning Environment

As a methodological basis for the creation and application of the module of visualization of three-dimensional objects of virtual reality, integrated into the cloud Moos platform, a concept is proposed, which uses the following parameters of the environment[2]:

1) the mechanism of interaction of the educational platform with the students by using the genetic algorithm;

2) ensuring the operation of self-learning circuits, learning management and educational platform;

3) creation of the educational environment, models and format of training that are adequate to the chosen subject area and motivation tasks.

The work of the contours of self-learning, learning management and management of the educational platform is shown in Fig. 1.

This approach in training solves the following problems:

- to use optimal technical and technological solutions in order to take them for the reference conditions that are necessary for the calculation of the values of didactic criteria;

- gain skills in developing rational strategies for solving complex and multicriteria applications;

- implement the control loops in the learning process.

A schematic representation of the educational platform is shown in Fig. 2

The obtained results are the necessary basis for the effective use of the latest technical and technological solutions in the educational environment.

The creation of such an environment, models and format of training with an adequate subject area and motivation tasks is used on the basis of the use of 3D - virtual systems. In such an environment, it is possible to achieve the criteria of adequacy to the real world due to the presence of both functional and spatial correspondence. For this purpose, the module of adaptive visualization of three-dimensional objects for an innovative platform in the MOOCs virtual educational environment is integrated into the training courses [3–5].

This technology is aimed primarily at the technical sphere of education, the study of which is the most difficult for the student.

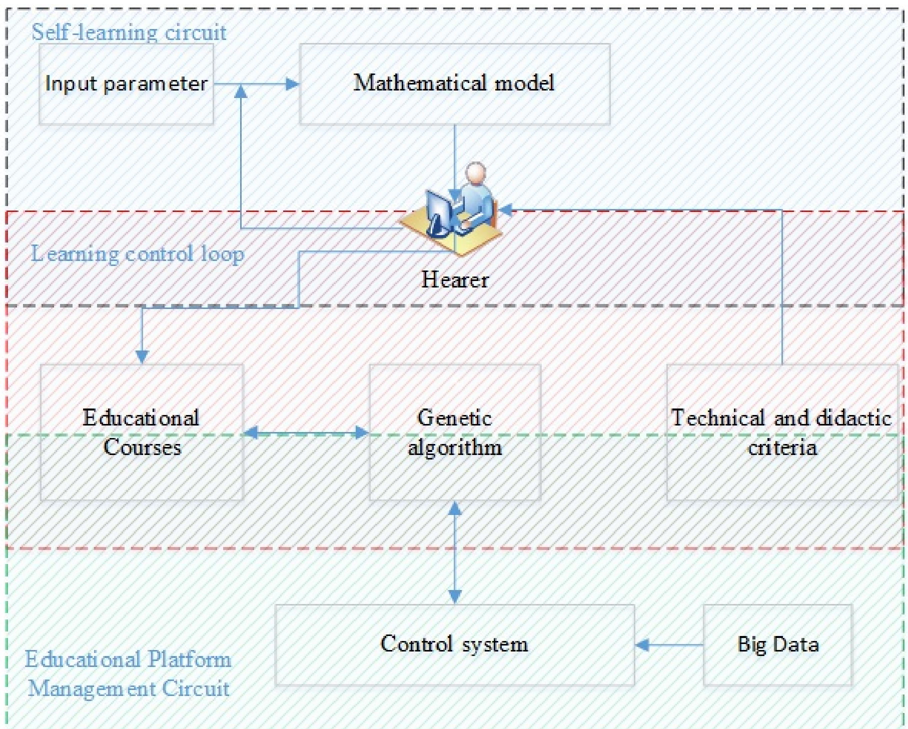

Fig. 1. Structure of the educational platform

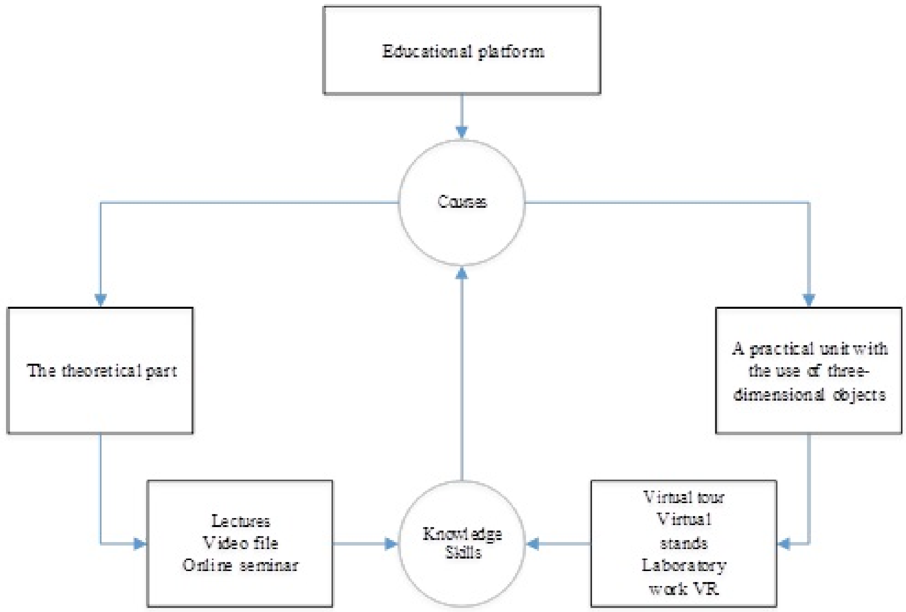

Fig. 2. Schematic representation of the work of the educational platform

4 Mathematical Model

To create a module for adaptive visualization of three-dimensional objects, a mathematical model is used with the use of applied instrumental systems. Systems of this level must meet the following requirements:

- interactive model description and task design;
- providing the possibility to change the model structure and its parameters;
- managing the process of modeling and problem solving;
- implementation of the exchange databases;
- presentation of data in different formats.

Based on the literature analysis [15–17], the SURF method has optimal requirements: The method allows to SURF [5, 10]:

1) find special points of the image (such points, the parameters of which differ from similar values of neighboring points);

2) to build the descriptor points (a build descriptor enables you to define a particular point);

3) change the scale value of the rendered scene.

Singular points are determined using the Hesse matrix:

$$H(x, y, z) = L_{x,y}(x, y, z)L_{x,y}(x, y, z)L_{x,y}(x, y, z)L_{x,y}(x, y, z) \quad (1)$$

where $H(x, y, z)$ is the Hessian; $I(x, y)$ - the location of the source image; x, y, z - coordinates of a three-dimensional object; L_{xx}, L_{xy}, L_{yy} - convolution of the image with Laplacian from Gaussian.

The convolution of the image with Laplacian of Gaussian can be represented as next functions:

$$L_{xx}(x, y, z) = I(x, y) * \frac{d^2 * g_z}{dx^2} \tag{2}$$

$$L_{yy}(x, y, z) = I(x, y) * \frac{d^2 * g_z}{dy^2} \tag{3}$$

$$L_{xy}(x, y, z) = I(x, y) * \frac{d^2 * g_z}{dxdy} \tag{4}$$

Combining SURF method for finding the plots in which was applied the textures when you rotate a three-dimensional scene and Shader X4 [5]. It is possible to obtain a three-dimensional scene that is efficient in performance and quality.

5 Experimental Part

The developed infrastructure in high-performance computing to obtain the final scene of a three-dimensional course when working with Big data is shown in fig. 3.

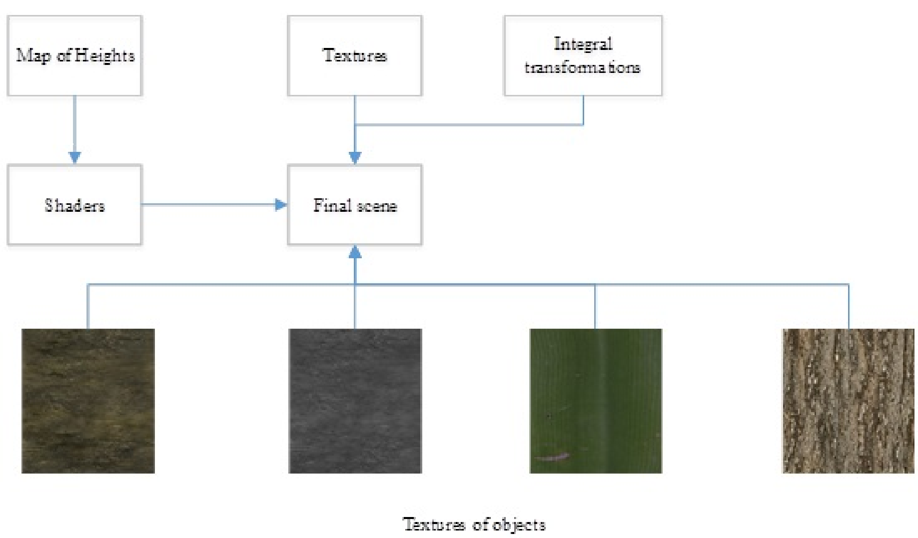

Fig. 3. Scheme for obtaining the final scene of the three-dimensional course

This approach in obtaining a photorealistic visualization of relief with a calculated texture allows you to combine different surface materials, adjusting the most optimal texture for each area of the relief surface taking into account its local characteristics. Each material is given a unique texture, which ensures high image quality even when considering the surface from a low height. The addition of procedural details and the use of noise and shaders allow for a more realistic image (Fig. 4).

a b

Fig. 4. Compare the visual results of the terrain display a) ShaderX 4 and b) a combination of ShaderX4 and Surf

Fig. 5 shows the effectiveness of the method.

The results of the dependence of the minimum number of frames per second (FPS) on the screen resolution in comparison with the use of ShaderX 4 are shown.

6 Conclusions

The article deals with the technology of virtual reality, through the formation of the three-dimensional scene for training students in distance learning. In the work done, three-dimensional models have been created, which are integrated into the educational platform and allow for a 360-degree view of the scene. The prototype of the module of adaptive visualization of three-dimensional objects for an innovative platform in the virtual educational environment is developed. A change in the dependence of the minimum number of frames per second on the resolution of the issued scene was revealed, a structural model of the cloud infrastructure for processing data visualization of three-dimensional objects was built.

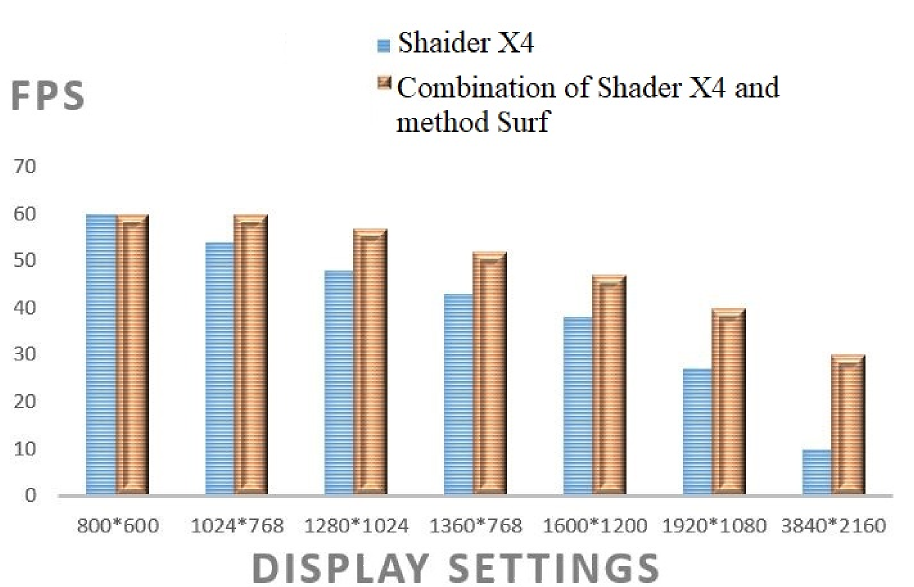

Fig. 5. The results of the dependence of the minimum number of frames per second on the screen resolution

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