

MATHEMATICAL APPROACHES FOR CREATION OF COMPLEX 3D MODELS AND THEIR APPLICATION IN EDUCATION

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Abstract

The methodology for creating Mixed Reality (MR) can be used as an important part of learning and for creating spatial thinking in students. 3D modeling, whether in lower secondary or high school, helps to develop a lot of skills and knowledge in computer graphics. Using this technology is an important tool in teaching students to find alternative solutions for different issues. The introduction of 3D technologies into a university information environment is beneficial for students and their professional preparation. 3D modeling is a three-dimensional computer graphics process, which involves creating a mathematical network representing any three-dimensional object using specialized software. The product is called a 3D model. It can be visualized as a 2-dimensional image through a process called 3D Rendering or used in a computer simulation of a physical phenomenon. They represent a 3D object by collecting points in the 3D space associated with different geometric structures such as triangles, lines, curved surfaces, etc. 3D models can be created by hand, algorithmic (procedural modeling), or scanned. 3D models are widely used everywhere in 3D graphics. In fact, their use precedes the widespread use of 3D graphics for PCs. Many computer games use previously released photos of 3D models as sprites before computers can render them in real time. In this article we will briefly describe some types of 3D Curves and Surface how they can be used in the creation of complex objects from 3D models. We will present examples of the geometry and physics of the virtual world in a mixed reality system. We conducted a survey of the possibilities for the introduction of new technologies using mixed reality in computer science education. We will present our results and our suggestions for new courses that raise students' interest in new technologies. In the paper will be presented the good practices from the University of Library Studies and Information Technologies and South - west University "Neofit Rilski" in this direction. The application of 3D technology in the preservation and promotion of the cultural and historical heritage will be demonstrated.

Keywords: education, augmented reality, 3D visualization, cultural and historical heritage.

1 INTRODUCTION

3D models represent a 3D object by collecting points in the 3D space associated with different geometric structures such as triangles, lines, curved surfaces, etc. 3D models can be created by hand, algorithmic (procedural modeling), or scanned [1-4].

Today, 3D models are used in a variety of areas. Detailed organ models are used in the medical industry. The film industry uses them as heroes and objects for animated and real objects in gaming films. The video game industry uses them as assets for computer and video games. The scientific sector uses them as very detailed models of chemical compounds. The architectural industry uses them to demonstrate buildings and landscapes through software architectural models. The engineering community uses them for images of new devices, vehicles and structures, and many other applications [5]. [6] Over the past decades, 3D geological models have begun to be constructed in the scientific community as a standard practice. Almost all 3D models can be divided into two categories. Solid - These patterns determine the volume of the object they represent. They are more realistic but more difficult to build. Patterns of this kind are mainly used for nonvisual simulations, such as medical and engineering simulations. Shell / boundary - these patterns represent the surface of the object, not its volume[7], [8]. These models are easier to work than solid models. Almost all visual models used in games and movies are such models. Since the appearance of an object has largely shrunk from the outside of the subject, boundary patterns are common in plotting. Two three-dimensional surfaces are a good analogy for the objects used in the graphs, although quite often these objects are not numerous. Also, setting levels is useful for deformation of surfaces that are subject to very topological changes, such as liquids. 3D modeling has recurring concepts that usually appear as abbreviations. Here are some of the most up-to-date: CW, center of window, in reference

to the visualization window; RP, view reference point; VPN, view plane normal; VUV, view up vector; FOV, field of view ; VRC, view reference coordinates ; WCS, world coordinates system

The most popular ways to present a model are three: Polygonal modeling - points in the 3D space, called peaks, are linked to segments to form a polygonal mesh. Most of the 3D models today are built as textured polygonal patterns because they are flexible because computers can make them fast[10], [111-14].

Curve modeling - Surfaces are determined by curves that are affected by the weighted control points. The curve follows the points. Increasing the stroke of the point will pull the curve closer to that point. Digital Sculpting - Although a relatively new method, 3D sculpting has become very popular in recent years.

2 METHODOLOGY

Nowadays, the amount of information is so great that visualization has become a tool for transforming data from different sources into graphical form, where users intuitively, through their sensory perceptions, easily find the relationships, structures, and anomalies they are looking for. Contemporary cartography can be represented as a visualization of geospatial information at different levels of detail, dimensions, formats and applications, and maps - as a means of representing reality in a visual, digital or tactile way. Making 3D maps is possible through the combination of cartography and computer graphics. With advances in hardware and software technologies, building graphics is easier and faster. 3D mapping allows you to display many different features. Software applications easily represent different viewpoints and the user is facilitated by the presentation of visually receptive information. Interactivity is an important feature for achieving effective visualization. As a result, the user is able to accept a larger amount of data under certain processing conditions. For better perception of 3D maps by both the user and the compiler, it is necessary to develop cartographic design principles. One of the first attempts to describe variables in modeling cartographic products was made in [Mapping Principles of Designing 3D Maps - Contribution to Mapping Theory] by [Haerberling S., 2004]. The study was conducted by the Institute of Cartography, ETH Zurich. The list contains 19 sample cartographic principles for designing 3D maps that follow the order of the design process - modeling, symbolization and visualization. At the same time, there are two basic modeling functions - the degree of abstraction and the parameters that determine the proportions of the objects on which the 3D map depends. Innovative technology for creating 3D maps, presented as cheap and easy, is "From paper to virtual map". The technology is presented in eight steps that include the design of all three categories of objects that each 3D map contains - primarily, secondary and extra content.

Depending on the user's requirements, the output data, and the application of the card, some of the steps may be excluded. There are various other 3D mapping technologies that require very good financing and highly qualified staff. The latest technological advances allow us to map through robots, defining latitude, longitude, relative height and direction at each mapped point. The technical process of making a 3D map is of utmost importance, as data entry in all four stages - design, modeling, visualization and signage, affect the final vision of the map. All steps are done interactively. In the process of designing each cartographic product, users' needs must be taken into account. Knowledge, experience, and cause of product use (eg goals, location, time) should be taken into account. At this stage, the understanding of future users, their needs and the topics of interest to them indirectly influence the choice of the type of card.

The process of modeling reality involves converting and merging different topographic and thematic information and images (DTM, vector data, raster textures, etc.). From the raw data, a complex 3D model of the Earth's surface can be obtained, especially when using dynamic and interactive features in the 3D map. In the construction of the sign system, graphical features are applied to the individual objects in the model. These are the shape, size, color, brightness, texture and other graphic features. Also, the actual earth surface can be changed when generalization is needed. The graphical image of each object class is defined both in the creation of a traditional legend of a map and in consideration of the rules of cartographic generalization. The structure of the legend does not affect the type of objects as they are created. The last step is visualization of the 3D model on the map. This is achieved through software and application. Finally, the mapped elements are visible to the user thanks to the projection parameters and the inevitable interaction of light and shadows. Therefore, for the final image it is necessary to use the luminaires, the camera and the parameters of the output file format should be determined. Cartographic modeling of 3D maps provides many possibilities for getting the image. These options are grouped according to the type of elements that are characteristic of the different stages in the modeling process - modeling of the digital terrain model, view of the objects, perspective, climatic and natural phenomena and others that affect the appearance of the map visualization.

Unlike raster patterns that perform the entire space, vector model data is built into straight lines occupying part of the space. This is, in fact, the advantage of vector models, namely that they need a less memory memory mode and a lesser amount of time for processing and rendering. In order to construct the object vector patterns, it is necessary to join points with straight arcs and polylines. The vector vector object is derived from the line of lines. The geo-information system working with vector models is called GIS.

Of course, non-abstract lines and points are applied in the sensitivity, but objects involving lines and areas (areas) occupying space in space, as well as the complex interrelationships between them. And for this full vector data model depicts spatial data as a sum of the following main parts:

Geometric (metric) objects (dots, lines and polygons) attributes-attributes related to objects, relationships between objects.

Vector patterns depict all types of coordinate patterns: dot, linear and area. The type of coordinate patterns is determined by a base line item following the way. The dot is called the zero-length line and the line-of-line length. The area is a series of interconnected linear parts.

Vector patterns are formed in different ways. The most famous of these is a vector-scanned (raster) image. It is a decoupling of vector objects with scanned rendering and receipt as a vector form. Another way is to build the model in the process of editing.

Some objects are vector-like using, for example, paths, boundaries of certain land areas, boundaries of regions, etc. For this, vector patterns are typically used as a collection of boundary plus data, stretching linear or meshed objects. The vector shape is superfluous for analysis and targeting.

For example, network analysis, route traffic development, traffic intensity analysis,

Vector pattern can have any given line width, including zero. This is their advantage over the raster, where the point or line object should occupy a group of cells. This creates dependence on the size of the resistor object by the size of the screen [9]. For this, vector data is more accurate than raster because vector data can be encoded with any reasonable degree of accuracy that is limited by the capabilities of the internal coordinate rendering method. Typically, 8 or 16 decimal characters are used when presenting vector data (either unidirectional or double precision). Only certain classes of data obtained during the measurement process correspond to the accuracy of the vector data. These are data obtained from accurate capture (coordinate geometry), maps of small stretches compiled by topographical coordinates and political boundaries determined by accurate capture.

Not all natural phenomena have distinct clear boundaries that can be depicted as mathematically defined lines. This determines the dynamics of phenomena or ways of summing up spatial information. Soils, types of vegetation, slopes, places inhabited by wild animals - these are objects that occupy precise boundaries. For this, we use both vector and raster data to fully exploit the phenomena of reality, using their advantages [6] [15], [16], [17].

3 RESULTS

Parametric description of surfaces. Surfaces set in the form $X = X(u, t)$ $Y = Y(u, t)$ $Z = Z(u, t)$ where u, t are parameters different in range belonging to the class of parameters. With a fixed pair of values u, t can calculate the position of a point on the surface. For full view on the entire surface You should list the plurality of pairs u, t with multiple changes for calculating the value of every pair of X, Y, Z in the three-dimensional space. Each surface can be represented by parameters. Here are some examples of descriptions by parameters [8]:

Plane passing through a point (X_0, Y_0, Z_0) and vectors n_1 and n_2 rising from this point, determined by the equation $r = r_0 + un_1 + tn_2$ or in the expression for component $X = X_0 + un_1X + tn_2X$, $Y = Y_0 + un_1Y + tn_2Y$, $Z = Z_0 + un_1Z + tn_2Z$, where $r = iX + jY + kZ$; $r = iX_0 + jY_0 + kZ_0$; n_mX ; n_mY ; n_mZ - vector projections n_m ($m=1,2$) along the axis OX, OY, OZ respectively. The above formula describes rectangle with the lengths of which are respectively $|n_1|$ и $|n_2|$, if the single vectors are located perpendicularly to one another and scope of variation is within the limits from zero to one.

Normal N_k plane, set in a parametric form can be defined as a vector work $N = n_1x + n_2y$. Vector N is oriented so that the triad n_1, n_2, N o define a ROCD.

The elliptical shape $(x/a)^2 + (y/b)^2 + (z/c)^2 = 1$ s parametrically represented in the form $X = a \cos \theta \cos \varphi$, $Y = b \cos \theta \sin \varphi$, $Z = c \sin \theta$, where θ - length, φ - wide. Surface of the ellipsoid is defined as follows::

$N=i b c \cos \theta \cos \varphi+j c a \sin \theta \cos \varphi+k a b \sin \varphi$. In general, $N=i N_x+j N_y+k N_z$ in the parametrically determined surface at point $M(X_0, Y_0, Z_0)$ have the form:

$$N_x = \begin{vmatrix} \frac{\delta Y}{\delta u}(\cdot) M & \frac{\delta Z}{\delta u}(\cdot) M \\ \frac{\delta Y}{\delta t}(\cdot) M & \frac{\delta Z}{\delta t}(\cdot) M \end{vmatrix}; \quad N_y = \begin{vmatrix} \frac{\delta Z}{\delta u}(\cdot) M & \frac{\delta X}{\delta u}(\cdot) M \\ \frac{\delta Z}{\delta t}(\cdot) M & \frac{\delta X}{\delta t}(\cdot) M \end{vmatrix}; \quad N_z = \begin{vmatrix} \frac{\delta X}{\delta u}(\cdot) M & \frac{\delta Y}{\delta u}(\cdot) M \\ \frac{\delta X}{\delta t}(\cdot) M & \frac{\delta Y}{\delta t}(\cdot) M \end{vmatrix};$$

specially important about the practice are bactericidal parametric surfaces. Cubic surfaces are the simplest forms of surfaces that help to achieve continuity of the integral function and its first derivatives. Typically, the backyard regions are smoothly curved rectangles that can be sheets of metal, paper, and other materials that are elastic. The disadvantages here are the difficult description of the surfaces as well as the large calculations. The main advantage of the parametric description is the possibility of placing geometric shapes on very complex surfaces, which in other methods is very complicated. For example, complex structures such as the spiral shell of a snail can be described using the parametric representation of the sum of three vectors. Description of type $f(X, Y, Z) = 0$ and many other surfaces is impossible.

The parametric description suggests that the light beam forming an image is a point on the subject. This complicates the use of computer algorithms for image synthesis. This, in turn, leads to limitations on the visuals properties: Illustrations of parametric surfaces, and objects have no shadows, transparency and reflection. Parametric surfaces are very easy to limit in space by defining the boundaries of the parameters.

In the XYZ coordinate system, each individual flat part of the element lies in a plane, which is described by the equation $f_1(X, Y, Z) = AX + BY + CX + D=0$ in matrix form $[X Y Z 1]P=0$, where $P=[A B C D]^T$. By changing the components of the matrix, it is possible to describe any position on the plane.

In the following figures (Fig 1. – Fig 5.) we will show a real surface model near Blagoevgrad. This model will be used in our next development to create a real 3D model of an ancient city.

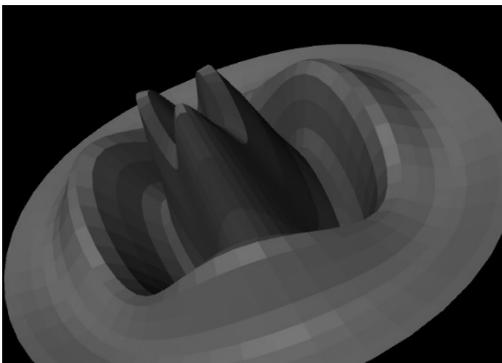


Figure. 1. Parametric surface from MathMod, processed in Maya.

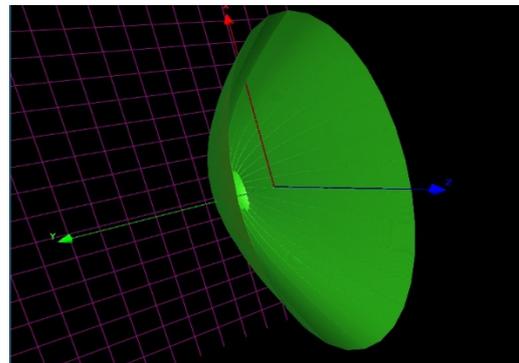


Figure. 2. Parametric helix from MathMod.

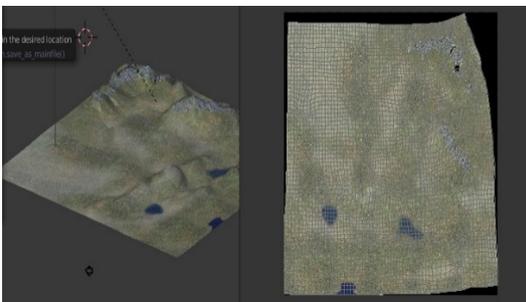


Figure. 3. Develop a 3D model.

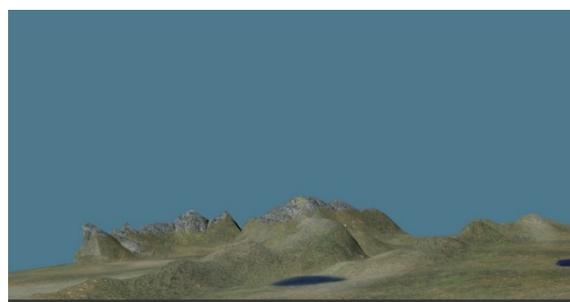


Figure. 4. 3D surface model near Blagoevgrad.

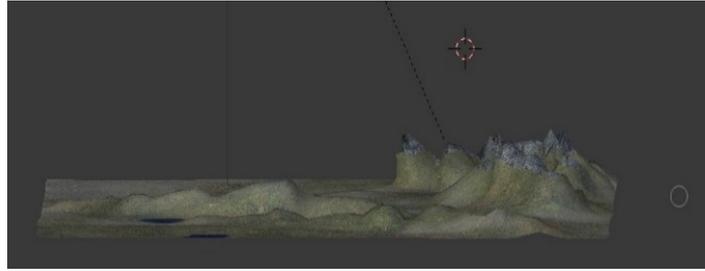


Figure 5. Create landscape luminance.

3D modeling is an art of creating objects and images using computer software. 3D models are widely used everywhere in 3D graphics. In fact, their use precedes the widespread use of 3D graphics for PCs.

Many computer games use previously released photos of 3D models as sprites before computers can render them in real time. Today, 3D models are used in a variety of areas. Detailed organ models are used in the medical industry. The film industry uses them as heroes and objects for animated and real objects in gaming films. The video game industry uses them as assets for computer and video games. The scientific sector uses them as very detailed models of chemical compounds. The architectural industry uses them to demonstrate buildings and landscapes.

In order to make a quality model, we need to learn all the details and features of the program, be familiar with similar programs and the ability to exchange files between them, use of additional literature and the Internet, study of models created by others with the program and integration of a lot of labor. Also, when modeling a real object, we must take into account its individual shapes, dimensions and characteristics.

From our survey conducted at South-West University "Neofit Rilski" and the University of Library and Information Technology, many students want to start a job related to computer graphics and participate in such projects (Fig. 6-8).

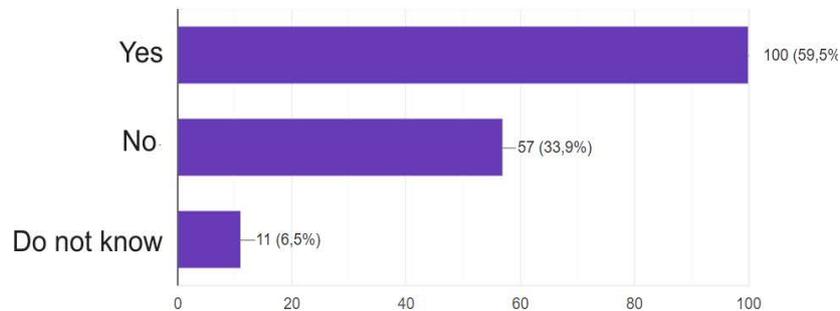


Figure 6. Result of a survey for participation in projects.

Could you start a career in computer graphics

168 answers

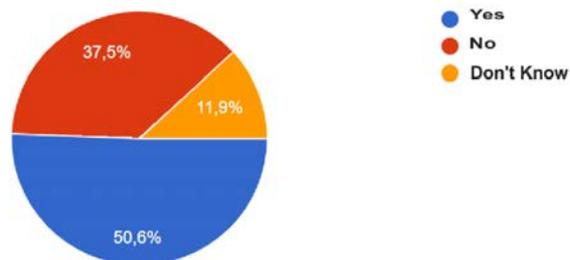


Figure 7. The result of a survey to start a new career.

Would you like to include teaching materials in a virtual or augmented reality system in your lectures and exercises



168 answers

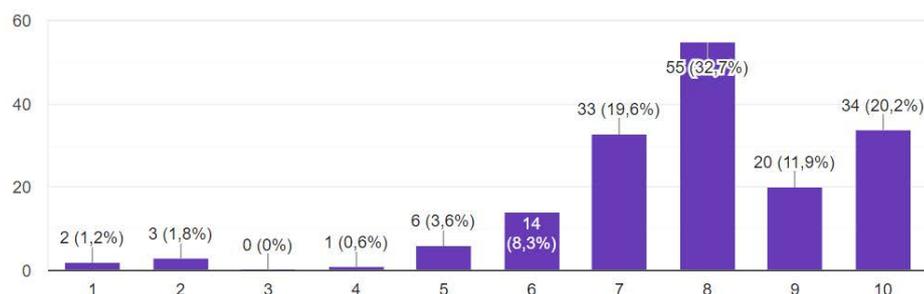


Figure. 8. The result of a questionnaire survey for putting new materials into lectures. Results increase from 1 to 10 max.

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REFERENCES

- [1] A. Tavanaei et al., "Empirical evidence, evaluation criteria and challenges for the effectiveness of virtual and mixed reality tools for training operators of car service maintenance" *Computers in Industry*, vol. 67, pp. 17-26, Publication 2015.
- [2] A. Tavanaei et al., "Optimal reduction of solutions for support vector machines" *Applied Mathematics and Computation*, vol. 214, pp. 329-335, Publication 2009.
- [3] A. Behaviors, vol. 81, no. 8, pp. 1-11, Publication 2018.
- [4] D. Rogers, J. Adams *Mathematical foundations of computer graphics*. M.: Publication 2001.
- [5] H. Chen et al., "The rise of deep learning in drug discovery" *Drug Discovery Today*, vol. 23, no. 6. pp. 1241-1250, Publication 2018.
- [6] I. Stojmenovic, A. Ruhil, D. K. Lobiyal, Voronoi diagram and convex hull based geocasting and routing in wireless networks, *Wirel. Commun. Mob. Comput.* Vol. 6, pp. 247–258, Publication 2006.
- [7] I.P. Tussyadiah et al., "Virtual reality, presence, and attitude change: Empirical evidence from tourism" *Tourism Management*, vol. 66, pp. 140.-154., Publication 2018.
- [8] K Kise., Sato A., Iwata M. Segmentation of Page Images Using the Area Voronoi Diagram, vol. 70, no 3, pp. 370-382, Publication 1998 .
- [9] M. Traykov, S. Angelov, and Yanev, N. "A new heuristic algorithm for protein folding in the hp model" *Journal of computational biology*, vol. 23, no. 8, pp. 662.-668., Publication 2016.
- [10] M.E. Beheiry et al., "Virtual Reality: Beyond Visualisation" *Journal of Molecular Biology*, in press, accepted manuscript, Available online 7 February 2019.
- [11] N. Vaughan, B. Gabrys, V. N. Dubey, "An overview of self-adaptive technologies within virtual reality training" *Computer Science Review*, vol. 22, pp. 65-87, Publication 2016.
- [12] S. Koller et al. "Using virtual reality for forensic examinations of injuries" *Forensic Science International*, vol. 295, pp. 30.-35., Publication 2019.

- [13] S. M. LaValle VIRTUAL REALITY, Cambridge university press, <http://vr.cs.uiuc.edu/>, Publication 2017.
- [14] V.P Ivanov and Batrakov A.S. Three-dimensional computer graphics / Ed. Gm Polishchuka. - M .: Radio and communication, 1995
- [15] D. Stoilova Tax Structure and Economic Growth: Evidence from the European Union, Contaduría y Administración Vol. 62, no. 3, 1041–1057, Publication 2017.
- [16] Borisova N., An approach for Ontology Based Information Extraction (OBIE), списание Information Technologies and Control (ITC), Vol. 12, no. 1, pp 15–20, Publication 2017.
- [17] E. Stavrova, , M. Trencheva , E. Koletca, , B. Kostadinova, , (2018) “System for monitoring the economic situation, development and the contribution of the tourist industry to increase the welfare”, International Scientific Conference „The cultural corridors of south-eastern Europe: cultural tourism without boundaries”, Santorini - Greece, 02-10 October 2018, pp. 88-97, Publication 2018.