Analysis of 3D Technologies for Stereo Visualization

Penio Lebamovski

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Penio Lebamovski
Institute of Robotics, Bulgarian Academy of Sciences, Sofia, Bulgaria
p.lebamovski@abv.bg

Abstract— **The article presents a new author's software. It makes a comparative analysis between 3D technologies for stereo visualization with application in teaching the discipline of stereometry, designed for middle and high school students. In the proposed system, rendering geometric models can be performed both through traditional visualization and through 3D active and passive technologies and systems with and without immersion. The system allows importing and exporting 3D files with the extension .obj and then printing to a 3D printer or add to an augmented reality device. The software can be used for stereo visualization of random 3D models from various scientific fields**

Keywords: stereometry, stereo system, 3D technology, java nodes

I. Introduction

One of the fastest-growing areas of the modern world is 3D technology, which in recent decades has found application in almost all spheres of society, including education. What until recently looked like science fiction is a reality today. The principle of 3D visual stereo is based on binocular parallax. One of the most important features of 3D technology is making the invisible/visible and the inaccessible/accessible. By means of it, new concepts are learned and higher levels of concentration are showed. The introduction of 3D systems in the education of the Republic of Bulgaria is currently hindered by many objective reasons, such as the lack of high-tech infrastructures and standards, as well as the insufficient awareness of potential consumers about the benefits of the new technology. These limitations can be overcome in the near future. Despite the constraints, experts predict the active introduction of 3D systems in secondary and higher education, and the first steps in this direction have been taken. The use of these systems in education will lead to a paradigm shift in how people view school and university education [12]. The application of this technological innovation in the education sector will improve how pupils and students will acquire new knowledge [1]. Three-dimensional modeling and animation of information will provide teachers with high-quality teaching materials and programs that will help students more easily absorb understand/perceive the material studied, increase their motivation and ability to absorb learn large amounts of information.

Nowadays, practical effective teaching and learning are impossible without using new techniques based on modern information technologies and the innovations of the so-called "digital" pedagogy [8, 9]. Within a high-tech information-educational environment, 3D technology is an essential tool that helps teachers increase their professional capacity and students achieve their educational goals.

One of the most used in Bulgaria and worldwide software for training in stereometry is Cabri3D, Geogebra, and DALEST. After a study, it was found that only one of them allows for stereo visualization through 3D passive technology and a system without immersion. The report presents a new method for training in stereometry. This is called StereoMV (Stereo Math Vision), unlike the mentioned software, can be realized through an immersion system. This gives great opportunities to the user as they will have the right to choose both the type of technology and the type of system.

The article aim is to present a new stereoscopic training system. The system is aimed mainly at middle and high school students studying stereometry in the textbooks of Archimedes Publishing House. The report performs a comparative analysis between 3D technologies of systems with and without immersion realized by the stereoscopic system.

II. 3D Stereoscopic Systems

There are two types of stereoscopic virtual reality systems: with immersion and without immersion. These systems differ from each other in a specific way. Immersion systems require large funds for equipment and technique. Such systems are CAVE (Cave Automatic Virtual Environment) and HMD (Head Mounted Display). Systems without immersion are desktop computers in which the virtual world is displayed on a specialized stereoscopic display and the customer is equipped with active 3D glasses [3]. With these systems, immersion in the virtual world is significantly less than with immersion systems. The advantage of these systems is that they are more affordable to use because they are relatively inexpensive. These systems can successfully find application in education. Realized stereoscopic monitor and the user is equipped with active 3D glasses.

III. Methods for Stereoscopic Visualization

The principle of 3D visual stereo is based on binocular parallax. The two images with parallax information are used, each of the images being seen by the corresponding eye, resulting in different incarnations. There are two methods to distinguish [6]:

- Distinction by display - in this method, though the parallax raster, both eyes obtain two different images. The advantage of this method is that it can lead to a stereo effect without the use of 3D glasses, i.e. the effect is obtained with naked eye [6].

- The second method - the two images are moved away from the eyes and presented to the observer with the help of 3D glasses, which can be: polarizing, anaglyphic, active, etc [6].

The second method was used for the realization of the system.

IV. 3D TECHNOLOGY

The stereoscopic vision techniques that are part of the proposed new software are: HMD, active glasses, passive glasses (anaglyph) and CAVE. There are several options for visual stereo. The first one uses the so-called active glasses, which alternate between the eyes in sync with the monitor. Stereoscopic perception requires each eye to receive a separate view of the scene. The view should be at a different angle and by according to the position of the head. The distance between the eyes is called interocular distance. The second way to generate stereoscopic objects on stage is by having two serial and different monitors [5]. This is precisely/exactly the way the HMD is ready to work, as each eye has its monitor. Here again, each eye has a different view, but there is no switching between the eyes and the two monitors are constantly on [5]. The display with which the three-dimensional perception is visualized is of two types: head-mounted or room mounted [2, 5]. Most displays are single screens without head tracking. Such systems are the simplest forms of room-mounted displays. In the case of the HMD, the screens are attached to the head (i.e. when the head moves, the screens follow it). There are several options for visual stereo. The first uses the so-called Head tracking that allows head movement instead of the standard mouse, joystick, keys, and other controllers.

A. HMD Vs Screen

The full view specification can be divided into two parts, namely the view position and the view volume [2, 5]. Here it is necessary to calculate two matrices depending on the specification. When using the HMD, the camera needs to depend on the movement of the head, so that when the user's head moves and rotates, the 3D view moves together with it. It is important that the relationship between the eyes and the screen don’t mustn't change. Therefore, the projection matrix remains constant [2]. When using room-mounted, the movement of the head changes the projection matrix but does not control the camera. This is a problem when watching stereo. With room mounted it is not necessary to use head tracking unless we are in stereo mode. Appearance settings depend on the location and orientation of the eyes. If the user's head changes position, the view also changes [2]. Dynamically recalculating the projection matrix and the view matrix is a very annoying task. Java allows tracking and supports features for automatic head tracking [5]. Where the view is considered a camera. A projection matrix represents the section definition. A visual matrix represents the position of the view. The first of the matrices are defined in the coordinate system, where the eye is located at the beginning of the view to the negative direction of the application z-axis (applicate) and up to the ordinate. On the other hand, in the view/camera, the eye is located at the beginning, looking down at z and up at y.

B. Anaglyph glasses

The glasses with which monitors are looked at have lenses (or color filters) with different opposite colors, most often in blue and red. [7, 13] This is a technology that is independent of equipment. No exceptional hardware support for 3D, etc. is required needed. It is only necessary to have anaglyph glasses. This technology is most often found in magazines, and the old technology in salons.

C. 3D active technology

With this technology, frames are alternated sequentially, first for one eye and then for the other [13]. The frequency of these frames is usually 120 Hz, 60 Hz per eye [13]. For the structure to be perceived by the viewer, special active glasses are used, which darken the glass of the eye which doesn’t have to see the frame that was displayed. Here, darkening alternate first in one eye and then in the other. The use of a synchronization device is also required. This technology requires special equipment such as a DLP projector with 3D Ready support. In the field of computers, the company that offers such a kit is NVIDIA [13]. Their equipment is called NVIDIA 3D Vision, and it is combined with a 120 Hz monitor. One of the disadvantages of these glasses is that they are expensive and need charging to work.

D. CAVE system

CAVE a projection system using techniques to project images on the walls, ceiling, and floor of a cube as large as a room. Subsequently, one can walk around the room using special stereo glasses, after which the system provides information about the image [3, 4].

V. RESULTS

The comparative analysis performed in the article is made on the basis of 3D technologies for stereo visualization, which are part of the proposed new software. 3D displays for stereo visualization are divided into two classes: head mounted and room mounted. The full specification of the 3D view is divided into two parts: view volume definition and view (camera).

Created by the author StereoMV stereo system is realized and operates under Windows operating system. The object-oriented Java language is used as a means of realization. The main parameters of the stereoscopic system are:

- Software functionality
  Visualization of geometric objects, such as: prism, cube, cone, sphere etc. Presentation of the objects: solid and transparent. Changing the color of the walls of geometric primitives Perform calculations Different operating modes, such as: normal, full screen, developments, stereo, etc.

- Additional features and contribution
  Unlike the existing software solutions for stereometry training, the proposed new program has additional features, such as:stereoscopic perspective, realized through active and passive technology and system without immersion. The software can also be implemented through an immersion system: HMD and CAVE. The generated geometric shapes can be converted to a .obj file and then printed on a 3D printer or added to an augmented reality device. The software can be used for stereo visualization of 3D models from other scientific fields.
- Technical means for the realization of the stereo system

The necessary technical means for the implementation of the stereoscopic system of 3D active technology are: graphics card, monitor for stereoscopic visualization, 3D active glasses and projector for stereoscopic visualization. Anaglyph glasses are needed for passive visualization. The software also enables implementation through immersion systems, such as: HMD and CAVE.

- Objects for stereo visualization
  The class from the JAVA 3D library - Shape3D sets the geometry and appearance of geometric objects. The primitives created in this way are known as Java nodes. The system allows for their conversion into files with the extension .OBJ. Nodes are created by a class inheriting Shape3D in the constructor, which calls two methods: one method sets the geometry of the object, allowing when creating the geometry of the object to determine color values on each of the walls of the figure. The second method defines the default appearance.

- The connection between software and systems with and without immersion
  The Canvas3D class is a component of the AWT library and extends the two-dimensional object into a three-dimensional one by including the necessary 3D information. It represents the canvas where three-dimensional objects are drawn. One of the stereoscopic visualization modes is Mixed Immediate mode. This mode is used by the stereoscopic system for stereo visualization through active glasses. The Canvas3D object was created to represent the rendering of geometric shapes. The createSceneGraph () method defines the application scene. The relationship between the program and the stereoscopic visualization techniques is made by inheriting a StereoMV main panel. The integration of immersion systems in the stereo system is done similarly. The same goes for non-immersion systems.

- Geometry and appearance of objects
  The main types of primitives used in generating geometric shapes are:
  - LineArray - draws lines defined by a pair of points, written in an array showing the topology of the object and information about its visualization.
  - TriangleArray - draws triangles defined by three coordinates written in an array. Crawling the peaks can be done clockwise or counterclockwise.

- Appearance object - This object type defines all display states that can be set as a component of the Shape3D class:
  - Coloring attributes - defines the color of the primitive.
  - Line attributes - determines the type of line, width and length.
  - Transparency - defines attributes that affect the transparency of the object. Set a value that is in the range 0 to 1.
  - Material - determines the appearance of the object in lighting, color, etc.

The GeometryArray class offers direct construction of the geometry of the object, using arrays of simple polygons, such as: lines and triangles. This class defines the vertices of the geometric object, as well as the interaction between them. The parameters used in this program code are the following:

- COORDINATES - coordinates of the vertices.
- NORMALS - normal.
- COLOR – 3 colors for the vertices of the geometric object, without alpha

- Realization of the system
  The system allows for the realization of both 3D active and passive technology. In order to add stereoscopic visualization using passive technology with anaglyph glasses, the following is required:

  - Two identical objects are generated, located with a slight deviation from each other. This is not necessary with active technology associated with the Mixed Immediate stereo mode.
  - One is assigned a material that defines the appearance in blue and the other in red.
  - Transparency should be added so that the information can be processed by the anaglyph glasses.

Most of the parameters in the stereo system can be to change dynamically. An example is the setting of the dimensions of geometric objects and the performance of 3D transformations. The distance between the two eyes when generating a stereo image in the passive technology program can be adjusted. While in the active technology it is set firmly with the following values for left and right eye: -0.01 and +0.01.

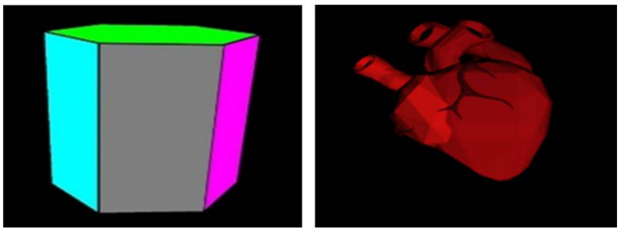
The system allows you to change the background color. For anaglyph glasses, the background is black by default. The goal is to make the objects stand out. With active glasses, the background can be arbitrary, as it does not affect the stereo effect. In addition to the two technologies mentioned, the software will be able to realized those related to the immersion systems: HMD and CAVE.

Initially, the software was implemented to work through a system without immersion. It is now possible to work through immersion systems. Therefore The rendering of geometric objects in immersion systems is determined by those in non immersion systems. Table №1 shows the results of the comparative analysis between 3D technologies, which are part of the proposed new software system. Advantages and disadvantages regarding their implementation related to StereoMV are highlighted.

The system allows for stereo visualization of java nodes, as well as files with the extension .obj. In Fig. 1a, Fig. 2a and Fig.3a shows a generated prism through the developed stereoscopic system. Refers to traditional, 3D active and 3D passive visualizations Fig. 1b, Fig. 2b and Fig.3b shows a model of a heart, which is downloaded from https://www.blendswap.com. Black is chosen as the background to get a better stereo effect.

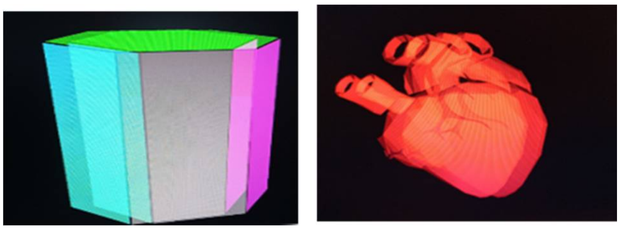
Table 1. Comparative analysis between 3D technologies realized by the new stereoscopic system

Type of Technology	Type of system	Advantage	Disadvantage
3D active/ 3D projector	Without immersion	- The colors are preserved - Great stereo effect - Short program code - Applies to .obj and nodes - Easy connection to the stereo system	- The stereo cannot be adjusted - Requires expensive equipment - There may be incompatibility with the video card
3D passive	Without immersion	- Applies to .obj and nodes - The stereo can be adjusted with a slider - Does not require expensive equipment	- Does not retain primary colors (blue / red only) - Small stereo effect - Long program code - Difficult to connect to the system
HMD/CAVE	With immersion	- The colors are preserved - Very large immersion effect - Applies to .obj and nodes - Easy connection to the stereo system	- They are very expensive - Long program code



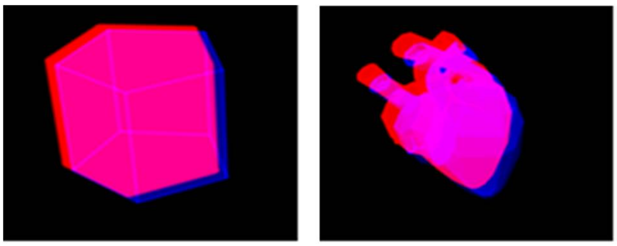
a) b)

Fig. 1. 3D Traditional visualization nodes and .obj file



a) b)

Fig. 2. 3D Active visualization nodes and .obj file



a) b)

Fig. 3. 3D passive visualization nodes and .obj file

Conclusion

The study of the teaching material in stereometry is one of the most problematic disciplines for students. A new stereoscopic system has been introduced to solve the problem of spatial imagination. Apart from geometry training, the software can also be used for stereoscopic visualization of three-dimensional models. It implements both active and passive visualization technology.

The report also provides a comparative analysis of the two types of technologies. The advantages and disadvantages are highlighted. Some require more equipment, More funds for equipment are required for the active technology and the visual effect is significantly more bigger. Passive technology does not require additional hardware, and it offers an excellent a good impact. The system can be used also by a HMD device via head tracking.

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