AUGMENTED REALITY IN EXECUTING PRACTICAL EXERCISES IN ENGINEERING GRAPHICS

Tashko Rizov MSc, University “Ss. Cyril and Methodius” in Skopje, Faculty of Mechanical Engineering – Skopje; str. Karpos II 1000 Skopje, Republic of Macedonia

Risto Tashevski PhD, University “Ss. Cyril and Methodius” in Skopje, Faculty of Mechanical Engineering – Skopje; str. Karpos II 1000 Skopje, Republic of Macedonia

Abstract

Introducing new technology in the teaching tools in execution of practical exercises is a must for every teacher in the world. Especially in technical high education keeping in pace with the new technology is of great importance. The new teaching tools should utilize the new technology in any possible way in order to assist the teacher in transferring the knowledge and assist the students in grasping that knowledge. By introducing augmented reality as means to better explain space and 3D objects to first-year engineering students we shorten the needed time to understand this matter. The teaching tool exploits the augmented reality technology and of-the-shelf software and hardware to facilitate the teaching process. Also, this new teaching tool has provided students with better visualization and easier understanding of space and the objects in it. At the same time, by utilizing this tool the students are actively participating in the execution of the exercises making them full concentrated and deeply interested on the topic.

Key words: augmented reality, 3D objects, engineering graphics, and visualization.

1. INTRODUCTION

Today's life is different to the one that existed not so many years ago. Our everyday life is constantly changing. The most important characteristics of our era may be the transformation, transmission and dominion of information. We live in an information society where the leading role has been given to new technologies. Our society could not be imagined without new technologies and their role both in this society and in human life in general.

Globalization - the increased flow of technology, economy, knowledge, people, values and ideas across borders has had a strong impact on higher education in terms of the quality, access and diversity of educational provision. The innovative use of new information and communication technologies (ICTs) in higher education, for both distance and face-to-face learning, has proven to be an important means for meeting the increasing demands for enrolments worldwide.

Higher education worldwide has experienced increasing massification, characterized by new students demanding extended access and flexible learning opportunities. Technology allows students to become much more engaged in constructing their own knowledge and cognitive studies show that ability is key to learning success.

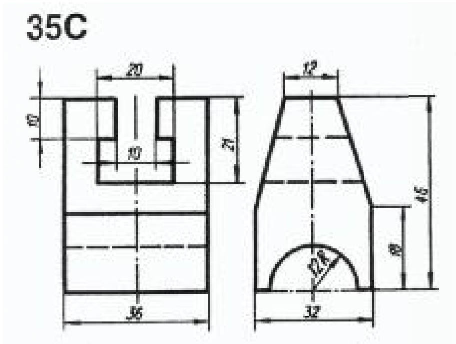
Modern technology has revolutionized people's way of thinking. It also changed the way of learning and ability to grasp knowledge. In an age of accelerating globalization, technological advances can play a key role in meeting growing demands for enrolment in higher education. Besides the growing enrolment, teachers have to work on maintaining the students' interest during the studies. By keeping to the conventional way of executing the classes this is impossible. Students' have become more demanding, expecting to learn the latest using the most modern methods, while in the same time their patience is dropping.

2. TEACHING ENGINEERING GRAPHICS

The Faculty of Mechanical Engineering in Skopje is part of the University "Ss. Cyril and Methodius"- Skopje. The Faculty was found more than 50 years ago at since the beginning offers courses in technical drawing, engineering geometry and graphics. Today, the Faculty offers 14 engineering curricula where in each of them the subject engineering graphics is mandatory.

The classes for this subject are divided in lectures and practical exercises. During the lectures the professor presents the theory and basic examples of how thing work in engineering graphics. While later on, the teaching assistants work with group of students in computer classroom on practical exercises. During the practical exercises, teaching assistants present to the students variety of examples from all areas of geometry and engineering graphics using the software Autodesk AutoCAD. In this process, the biggest challenge is for the teaching assistant to find out a way to help students to envision a solid body out of two orthogonal projections of the shape.

 ISBN 978-86-7892-405-7



Picture 1 – Engineering graphics exercise - orthogonal projections of a solid body

For more simple examples plastic or wooden models are used in order to facilitate this process. But this is not possible for more complex shapes; also it is not possible for presenting sections. In order to present this we usually use LCD projector showing solid model of the shape.

Although we try to make this process as simple as possible and we try to use the best didactic methods available it very common that number of students lose interest and become repulsive to the subject. This is due to the fact that some of them do not come from technical high schools and this is the first time they get in touch with geometrical shapes and bodies in space.

In order to avoid this obstacle teachers have to implement new ways of conducting the classes, especially the practical exercises. These new ways have to enable students to easier understand space and presentation of objects in it. This is only possible by enhancing the visual presentation of the objects in space and how objects are positioned in space. At the same time, this has to be dealt with use of the latest technology because that is what excites students and keeps them interested in the matter. Also, the new technologies are most feasible regarding efficiency and effectiveness.

3. AUGMENTED REALITY

Augmented Reality (AR) is a variation of Virtual Environments (VE), or Virtual Reality as it is more commonly called. VE technologies completely immerse a user inside a synthetic environment. While immersed, the user cannot see the real world around him. In contrast, AR allows the user to see the real world, with virtual objects superimposed upon or composited with the real world. Therefore, AR supplements reality, rather than completely replacing it. Ideally, it would appear to the user that the virtual and real objects coexisted in the same space. A more comprehensive definition of AR would be as a system that has the following characteristics: (1) combines real and virtual world, (2) interactive in real time and (3) registered in 3D. Augmented Reality enhances a user's perception of and interaction with the real world. The virtual objects display information that the users cannot directly detect with their own senses. The information conveyed by the virtual objects helps a user perform real-world tasks.

Augmented Reality might apply to all senses, not just sight. So far, researchers have focused on blending real and virtual images and graphics. However, AR could be extended to include sound, smell or tactile. At this paper the focus is only on sight as a human sense that needs to be augmented in order to achieve enhancement of the students' ability to visualize space and objects in it.

A basic design decision in building an AR system is how to accomplish the combining of real and virtual. Two basic choices are available: optical and video technologies. Each has particular advantages and disadvantages.

Focus can be a problem for both optical and video approaches. Ideally, the virtual should match the real. In a video-based system, the combined virtual and real image will be projected at the same distance by the monitor. However, depending on the video camera's depth-of-field and focus settings, parts of the real world may not be in focus. In typical graphics software, everything is rendered with a pinhole model, so all the graphic objects, regardless of distance, are in focus. To overcome this, the graphics could be rendered to simulate a limited depth-of-field, and the video camera might have an autofocus lens.

In the optical case, the virtual image is projected at some distance away from the user. This distance may be adjustable, although it can be fixed if the display is mounted to the user. Therefore, while the real objects are at varying distances from the user, the virtual objects are all projected to the same distance. If the virtual and real distances are not matched for the particular objects that the user is looking at, it may not be possible to clearly view both simultaneously.

Contrast is another issue because of the large dynamic range in real environments and in what the human eye can detect. Ideally, the brightness of the real and virtual objects should be appropriately matched. Unfortunately, in the worst case scenario, this means the system must match a very large range of brightness levels. The eye is a logarithmic detector, where the brightest light that it can handle is about eleven orders of magnitude greater than the smallest, including both dark-adapted and light-adapted eyes. In any one adaptation state, the eye can cover about six orders of magnitude. Most display devices cannot come close to this level of contrast. This is a particular problem with optical technologies, because the user has a direct view of the real world. If the real environment is too bright, it will wash out the virtual image. If the real environment is too dark, the virtual image will wash out the real world.

A key measure of AR systems is how realistically they integrate augmentations with the real world. The software must derive real world coordinates, independent from the camera, from camera images. That process is called image registration. Image registration is one of the most basic problems currently limiting Augmented Reality applications. The objects in the real and virtual worlds must be properly aligned with respect to each other, or the illusion that the two worlds coexist will be compromised. More seriously, many applications demand accurate registration. Without accurate registration, Augmented Reality will not be accepted in many applications. Registration errors are difficult to adequately control because of the high accuracy requirements and the numerous sources of error. These sources of error can be divided into two types: static and dynamic. Static errors are the ones that cause registration errors even when the user's viewpoint and the objects in the environment remain completely still. Dynamic errors are the ones that have no effect until either the viewpoint or the objects begin moving.

Image registration uses different methods of computer vision, mostly related to video-tracking. Many computer vision methods of augmented reality are inherited from visual odometry. Usually those methods consist of two parts. First detect interest points, or fiduciary markers, or optical flow in the camera images. First stage can use feature detection methods like corner detection, blob detection, edge detection or thresholding and/or other image processing methods.

The second stage restores a real world coordinate system from the data obtained in the first stage. Some methods assume objects with known geometry (or fiduciary markers) present in the scene. In some of those cases the scene 3D structure should be pre-calculated beforehand. If part of the scene is unknown simultaneous localization and mapping (SLAM) can map relative positions. If no information about scene geometry is available, structure from motion methods like bundle adjustment are used. Mathematical methods used in the second stage include projective (epipolar) geometry, geometric algebra, rotation representation with exponential map, kalman and particle filters, nonlinear optimization, robust statistics.

However, video-based approaches can use image processing or computer vision techniques to aid registration. Since video-based AR systems have a digitized image of the real environment, it may be possible to detect features in the environment and use those to enforce registration. They call this a "closed-loop" approach, since the digitized image provides a mechanism for bringing feedback into the system. For example, in some AR applications it is acceptable to place stationaries in the environment. These stationaries may be LEDs or special markers. The locations or patterns of the stationaries are assumed to be known. Image processing detects the locations of the stationaries, and then those are used to make corrections that enforce proper registration.

4. AUGMENTED REALITY IN EXECUTING PRACTICAL EXERCISES IN ENGINEERING GRAPHICS

In order to solve the above described problem a comprehensive solution had to be created. The solution is consisted of hardware and software with specifically designed architecture. The solution should provide the ability for students to visualize a 3D solid body out of two orthogonal projections of the same body printed in black on a white paper.

On the market today a variety of software packages exist for augmented reality. They are developed with a main goal to help the users to easily create an augmented reality scene. Depending on the level of computer literacy, especially on the level of knowledge of computer programing, different software is available.

Basically, no matter which of the existing software for creation of AR scenes is going to be used the procedure for its use and the design of the complete system is pretty much the same. One always needs a personal computer, regardless of its physical shape (desktop, laptop, tablet or smartphone). Depending on the AR software used different operating systems are compatible. The majority of the available software is compatible with Windows, Android and iPhone. In the system architecture, besides the personal computer a camera is necessary. The camera should be capable of capturing video with at least 30 frames per second with a resolution of at least 800x600. In order the AR scene to be created a marker is needed. The marker is the element that will assist in avoiding the biggest problem with AR scenes and that is registration. For a marker we can use a simple robust black-and-white shape or a picture. In both cases the marker has to be fed to the AR software. Some of them enable the user to create the marker directly in the software application. The final required element to create the AR scene is the 3D virtual object. This can also be video. In our case we will use a 3D solid model, created using Autodesk AutoCAD and modified using Autodesk 3D Studio.

Picture 2 – Augmented reality using marker

After the scene is created, the marker defined and fed to the AR software application together with the virtual object the augmentation of the reality can take place. The camera will record the real world and the feed of that can be presented on the computer screen. While the camera is used as a reader for the AR marker, the computer or mobile phone provides the screen for projecting AR. When the defined marker is introduced into the frame the software application will detect it and then it will track it and project the desired virtual object on it. The user can select from the available options for projection of the

 ISBN 978-86-7892-405-7

virtual object, either directly on the marker or on an offset of it. The process is the same regardless of the marker used.

For the use of the above described system for the execution of practical exercises for engineering graphics we will use a desktop personal computer, a Logitec C310 web camera with resolution of 1280x720 and 30 fps. For creating the AR scene we will use the software application of HITLab from New Zeeland called BuildAR.

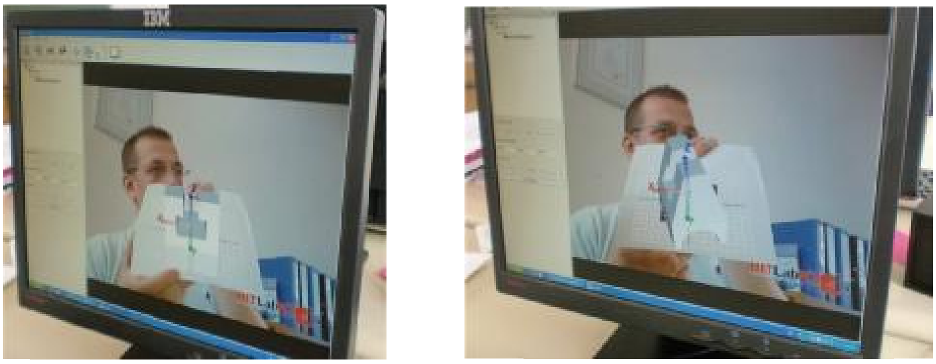
This software application enables the user to create the marker. In this case we will use robust black-and-white marker in order to provide easier and accurate tracking with best ability for movement and rotation.

Picture 3 – Video captured by the camera previewed in BuildAR

As a virtual object we will use the 3D solid model of the shape represented by two orthogonal projections in the students' exercise book. When the software is started it detects the available video capturing device and it shows the video captured by it (see Picture 3). When the marker is introduced into the frame the software detects it and recalls the previously defined virtual object.

Picture 4 – Introducing marker

The user is able to see the 3D solid object placed on the top of the marker. As the user is moving the marker the software is tracking it and following in order to project the virtual object all the time on the specific location. When presetting the AR scene and defining the position of the virtual object in relation to the marker the user should define the coordinates of the virtual object. Specifically this software application gives the user the ability to move, resize and rotate the virtual object.



Picture 5 – Preview of augmented reality

5. CONCLUSION

This paper presents the basics of augmented reality and the ability to use this technology as a didactic tool in every day work in higher education. Keeping the students' interest and at the same time facilitating the learning process is of paramount importance for the students, the teacher, the education institution but also for the country.

Using augmented reality in execution of exercises in engineering graphics has shown remarkable results. This tool helps the teacher to vividly explain the position of shapes in space and how the complete geometry of an object can be interpreted from its orthogonal projections. In the same time, this tool keeps the interest of the students with the bear fact that it is new and attractive as a method, but also provides them with the ability to physically move the virtual object and explore its geometry in space.

This results in shortening the needed time to execute the exercises for engineering graphics, and at the same time lowering the burden on the teacher for better explaining the exercises. Last but not least, this method enables bigger number of students to pass the course of engineering graphics with ease.

6. LITERATURE

1. Azuma R.: *A Survey of Augmented Reality, Teleoperators and Virtual Environments*, August 1997, USA, pp. 355–385.
2. EDUCAUSE Learning Initiative: *7 things you should know about augmented reality*, September 2005.
3. Cobzas D., Jagersand M.: *A comparison of viewing geometries for augmented reality*, University of Alberta, Canada.
4. Yeh M., Wickens D. C.: *Display Signaling in Augmented Reality: Effects of Cue Reliability and Image Realism on Attention Allocation and Trust Calibration,* Human Factors: The Journal of the Human Factors and Ergonomics Society 2001 43: 355.
5. Artag, Goblin XNA
6. ARToolKit AND ARToolKit Plus, ARToolKit for iPhone
7. Studierstube Tracker, Studierstube ES
8. Metaio UnifEye
9. HITLab BuildAR
10. Point & Find (Nokia Research on AR)
11. Total Immersion D'Fusion
12. YDreams SimVideo
13. Linceo VR3.0
14. FLARtoolkit (for Flash)
15. Mxrtoolkit (open source)
16. ARSight (Google earth on your desktop)