UNIVERSITY OF NOVI SAD
TECHNICAL FACULTY
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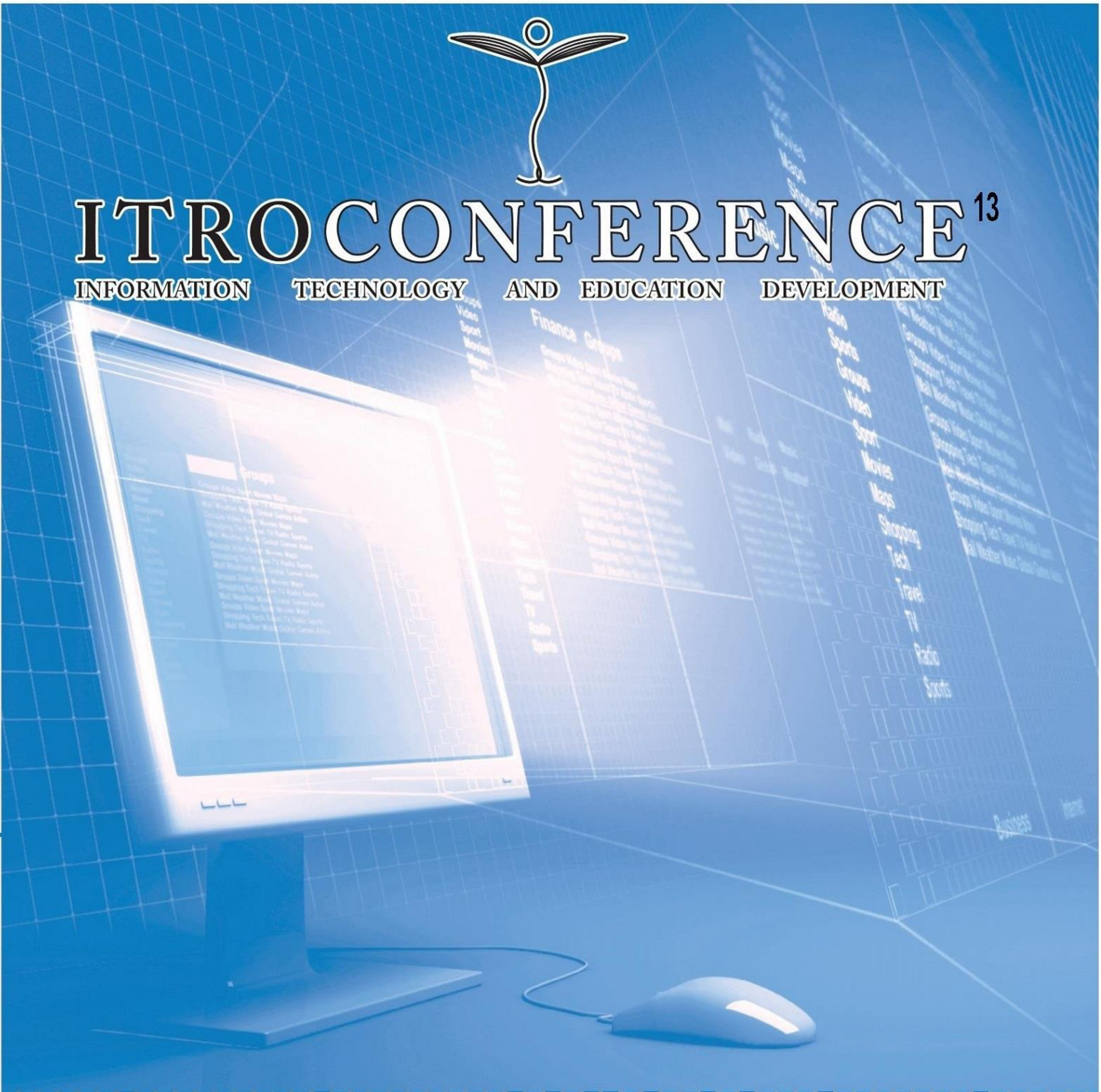
INFORMATION TECHNOLOGY AND EDUCATION DEVELOPMENT



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PROCEEDINGS

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CONTENTS

The Use of Augmented Reality in Geometry Teaching

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Abstract – Digital media nowadays create new ways to teach, learn and interact. Prospective teachers are using technology to transfer their knowledge in a more interesting and accessible way, while at the same time making students more engaged and motivated. AR, as a technology, has the potential to be an effective learning tool in formal and informal learning environments. This paper, present the development of the AR application for geometry teaching for primary school students. By augmenting the student's vision we enhance their ability to visualize what they are trying to learn. With the developed AR application, they can learn to make the differences between 2D and 3D shapes and how they relate to one another. The designed application is built using a WebAR-based approach and marker-based detection technology.

I. INTRODUCTION

Rapid development of the technology has influenced its inevitable entrance in the learning processes. Educators are constantly looking for resources and tools to get students engaged, motivated and excited about the content they are teaching [1-6]. An interesting option nowadays is augmented reality (AR) [7,8]. The AR technology can be used to assist the teacher in transferring the knowledge and assist the students in grasping that knowledge.

Augmented reality refers to technologies that dynamically blend real world environments and context-based digital information. It expands the physical world, adding layers of digital information onto what we can see with the naked eye. Three characteristics are important for augmented reality [9]: 1) combining real and virtual world 2) allowing real-time interaction 3) aligning real objects or places and digital information in 3D.

AR applications can be divided into two main categories, according to the used device: optical-based and video-based applications. In optical-based applications, various AR glasses such as HoloLens or Magic Leap are used as AR devices. They enable users to visually perceive reality that surrounds them, complemented with virtually designed objects. However, the usage of glasses as additional equipment, increases the costs of the AR system. In video-based applications, a real image received via video cameras is combined with virtual images on the screen of a computer or a mobile device. Smartphones, tablets or computers equipped with digital cameras can be used as AR devices in this case. The availability and prevalence of these devices allows video- based applications to be used in a variety of fields.

II. USING AR IN EDUCATION

AR technologies have been around for more than 50 years, but only the recent proliferation and consumerization of mobile technologies made affordable AR systems available for the broad public. It has been asserted that education is one of the most promising application areas for AR [10].

Augmented reality can be integrated into the classroom in all grades and across the curriculum. Various studies have examined the use of AR-based technologies for teaching and learning in various subjects and context: natural science, medicine, engineering, languages, history, arts and in various learning environments: kindergartens, primary schools, secondary schools, universities, laboratories etc. [11,12].

Most students in all levels of education experience problems when learning math. These problems usually are related to their abstract thinking ability [13, 14, 15]. For example, students often have trouble understanding the topics of geometry and 3D objects, since teachers are using two-dimensional drawings while explaining 3D objects (or shapes). Visualization in mathematics is a necessary condition for a conscious understanding of the subject of study, which contributes to increase the interest in the phenomena and objects under study, activation of mental processes that determine the process of cognition and stimulation of the cognitive activity especially for preschool and schoolchildren.

To overcome these problems, educators need to improve students' spatial abilities. Some research studies have examined the AR effects on students' spatial abilities. Martín-Gutiérrez et al.

[16] produced an AR book (called AR-Deheas), designed for use in technical drawing courses. In their study, they reported significant positive effects of using the AR book on students' spatial abilities. Roca-González et al. [17] and CarbonellCarrera et al. [18] studied the effects of AR applications on university students. In both studies, the spatial orientation skills in students who were part of the experimental group increased significantly compared to the students in the control group. Lin et al. [19] conducted an experimental study with secondary school students. They divided the students by their mathematics achievements in three groups: high, medium and low achievement. Their results showed that AR applications had no significant effect on the spatial ability of high achievers, hada small but positive effect on medium achievers, and had a significant positive effect on low achievers.

Some researchers investigated the effects of 3D modeling technology on the students' spatial skills. Huang and Lin [20] conducted a study with high school students and showed that 3Ddiagrams improved mental rotation skills, while 3D modeling-printing technologies improved both mental rotation and visualization skills. Katsioloudis et al. [21] examined the effects of two-dimensional drawing, versus 3D models and found that the students who printed their 3D models increased spatial skills more significantly than those who made two-dimensional drawings. All these findings indicate that students are more engaged and learn better when they have the opportunity to visualize the objects. AR applications, with its 3D displays and interaction features, are considered a suitable tool for enhancing students' spatial ability and achievement.

III. WEB-BASED AUGMENTED REALITY

There are two primary ways for people to experience AR. One is application-based AR, and the other is web-based AR. App-based AR provides an immersive augmented reality experience that is accessible through downloadable apps. On the other hand, web-based Augmented Reality (WebAR), as its name suggests, is a technology that allows users to consume AR experiences through a web browser. This means that the application does not need to be downloaded on the user's device and can be used online. This offers users convenience as it simplifies the process of consuming AR, which, in turn, creates conditions for increasing the number of end users. The WebAR technology is still in its early stage, but it's growing rapidly, andis expected to replace app-based technology in the near future.

The main advantage of WebAR is how widely supported it is. This technology runs on any commonly available web browsers (including Chrome, Safari, Firefox, Opera, Edge, and several others). When it comes to devices, WebAR works on nearly any recent hardware, provided it has internet access and a camera. Specific aspects of AR, however, function better on newer, more powerful devices. Screen size also affects the user's experience, as complex features are easier to engage with on larger screens.

WebAR development is easy and flexible, due to available frameworks, that provide a solid foundation on which to build apps. In the following, we will list some popular frameworks for WebAR development.

- AR.js - is one of the most popular frameworks for developing WebAR solutions. It is a cross-browser Javascript lightweight framework that is used for WebAR development. It is compatible with Three.js for rapid WebAR development.
- Three.ar.js - is a helper library for creating WebAR-based solutions. It utilizes WebARonARCore and WebARonARKIT which enable developers to create mobile-based Android and iOS user experiences.
- ARToolKit - is based on ARToolKit open-source tracking library. It combines WebGL and Three.js for the rendering of 3D models. The support for this library is currently stopped, but it's still widely used for creatingWebAR experiences.
- Argon.js - is a JavaScript library known for the simplicity of creating WebAR-based user experiences. It can be used for both appand web development. This framework utilizes features like marker and image tracking and lays on a complex ordinary system.
- Awe.js - the main features of this framework are motion sensors, location-based solutions, and AR markers. It works using device APIs, WebGL, and WebRTC in the background.

- X3DOM - is an open-source framework andruntime for 3D graphics on the Web. It enables web developers to incorporate AR content into web pages, directly within the HTML itself. This eliminates the need for any external plugins or libraries, as the sceneis an integral part of the page.

Generally, there are two types of AR, based on the types of triggers: marker-based and markerless AR. Marker based AR, also known as image recognition AR, is the most commonly used in WebAR. It requires a designated marker (usually an image, logo, QR code etc.) to activate an augmented experience. The user is able to scan the marker using the phone/tablet/computercamera and a digital experience will appear. This allows the user to move around the marker and see the digital experience in 3D.

IV. APPLICATION DESIGN

The idea behind the developed application is to allow the end-users to preview or visualize the 3D Geometric Shape by scanning its geometric net template.

The designed application is built using a WebAR-based approach and marker-based detection technology. As a development framework we have used AR.js combined with the ARToolkit and the Three.js library. The application structure is composed of a Three.js scene, camera, and renderer, which are the main objects of the application. The ARToolkit source object is used as the main entry point of the application. The ARToolkit library utilizes three different objects:

- ArToolkitSource: this object is used to initialize the application and the browser window, and it's used for positional tracking. Since the application will use a webcam as the main source, the source type in the ArToolkitSource object was set as 'webcam'.
- ArToolkitContext: this is the context (main engine) of the application. It initializes the application's main functions like Projection Matrices, cameras, etc., and finds the markerposition in the image source.
- ArMarkerControls: it controls the position of the marking by using the Three.js controls API. The patterns for marker detection are defined there.

Regarding the 3D object that should appear on the screen, the predefined three.js 3D models were used. Five geometric shapes (cube, sphere, cone, cylinder, and tetrahedron) were defined using the THREE.Mesh function. These geometric shapes were chosen as the most basic 3D shapes, taught in introductory geometry courses (more geometric shapes can also be added in the future). Colors and textures for each of the geometric shapes were also defined.

In the development environment, each 3D shape is linked with a particular marker. As we mentioned earlier, we used the images of geometric shape nets, as a pattern marker. Markers are distinct patterns that cameras can easily recognize and process. They can be paper-based or digital image. When the application detects the marker, it identifies the corresponding 3D model and recalls it. Then the software renders the 3D model over the marker, making itvisible to the user (Fig.1). In this way the user's reality is augmented. The interaction between the user and the system is through movement of the marker. Students can move the marker or rotate itso they can see the object from all sides.

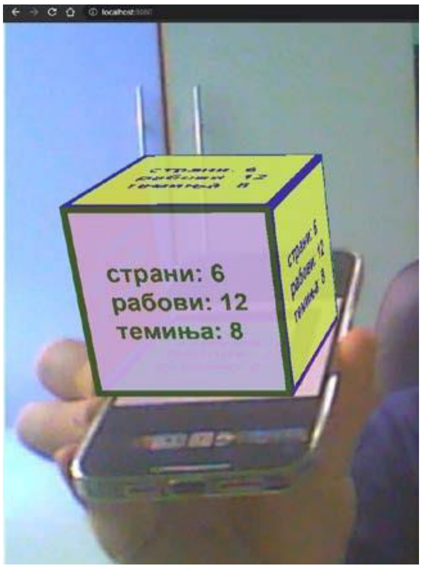

Figure. I. Developed app in action. Preview of the 3D shape-cube, on the top of its net template,along with basic characteristics: faces, edges and vertices.

V. CONCLUSION

The AR technology can be used to augment all of the user senses, although the vast majority of applications are focused only to the sight by combining virtual graphics with the reality the users see. In this paper the focus is on vision as one of the most important aspect in learning. The paper presents the development of the AR application for geometry teaching for primary school students. By augmenting the student's vision we enhance their ability to visualize what they are trying to learn. With the AR application they can learn to make the differences between 2D and 3D shapes and how they relate to one another. They will also learn the most important characteristics of 3D shapes, like: faces, edges, vertices… Exploring shape in a new and exciting way using AR gives students a broader depth of experience and a greater frame of reference when facing challenges in the future. When it comes to solving problems relating to 3D shape they will have a tangible first-hand memory of creating shapes from nets.

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