

Bringing Children Closer to Science and the Universe with New Technology

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Abstract - In the era of technology and social networks, it is difficult to attract children to science. To change this, three applications have been developed whose primary goal is not pure entertainment, but to educate and encourage scientific exploration in children. These applications were developed using new technologies, i.e. augmented reality, virtual reality and Ultraleap. Each application brings the intrigue of the universe to children in an interesting way by providing them with age-appropriate content and information about the universe. In these applications, interactive space travels can be taken to learn about the Sun and planets, and fun games can be played to stimulate interest in further observations and knowledge about the universe. The paper describes the applications and the multidisciplinary context of their development, as well as the potential of the new technologies in education.

Keywords - universe; serious game; augmented reality; virtual reality; Ultraleap

I. INTRODUCTION

The advancement of technology has opened numerous opportunities for innovation, and one such area is game development. Serious games are both entertaining and educational, making them a perfect tool to introduce complex concepts to children [1]. This paper presents the development of three serious games, named SolARsys, TouchSpace and UniVRse. These games were created by a team of college students attending the University of Zagreb, Faculty of Electrical Engineering and Computing as part of a course named Project. The project was part of Project SPARK, which involved the construction of an observatory and cosmological center in Križevci, Croatia. The developed games will be available to people in the lobby of the cosmological center and observatory [2][3]. Each game utilizes a different technology - augmented reality (AR), Ultraleap and virtual reality (VR) - and serves as an interactive learning experience for children. The team was divided into three groups, each focusing on one technology and application. This paper includes a section detailing the technologies used, followed by a section describing the development process of all three games. The final section is a product description that highlights the unique features of each game. The ultimate goal of the students project was to spark an interest in science among children through the use of new and engaging technologies. The development of SolARsys, TouchSpace and UniVRse demonstrates the potential of new technologies in education. By integrating augmented reality, Ultraleap technology and virtual reality the team

was able to create engaging and interactive learning experiences that could captivate and inspire children. These technologies have the potential to transform the way we teach and learn, providing new ways to explore complex concepts in a more intuitive and immersive way.

II. USED TECHNOLOGIES

In this chapter, the technologies used in the project are described. Subchapter A describes how augmented reality (AR) equipment works, i.e. Nreal Light Developer tool kit, NRSDK and Scrcpy. Subchapter B describes Ultraleap, while Subchapter C explains Virtual Reality (VR) technology, i.e. Meta Quest 2. Subchapter D explains why Unity was used to build the applications and its description is given.

A. Augmented reality – Nreal Light Developer tool kit, NRSDK and Scrcpy

The main components of the Nreal Light Developer tool kit are Nreal AR glasses, Nreal computing unit and Bluetooth Nreal controller. The glasses connect to the computing unit with a wire and use the computing unit as a power supply. They can be connected to the user's mobile phone or computer, in which case the screen from the mobile phone or computer is projected in front of the user, i.e., they have the function of an additional screen. The Nreal controller connects to the computing unit via a Bluetooth connection. When the user uses the controller, a white beam can be seen that represents the pointer used for selection and interaction with the AR elements [4].

The glasses have well-built spatial computing that includes motion tracking, plane detection, image tracking, hand tracking and tracking of real-time position of the glasses relative to the world and environment around them. Plane detection enables Nreal glasses to detect both horizontal and vertical flat surfaces in the environment. Image tracking enables recognition of physical images from the environment. Hand tracking enables tracking the position of key points of the user's hands and recognition of hand poses in real-time. Nreal glasses have 6 degrees of freedom achieved by identifying feature points and tracking how those points move over time. Combined with the sensor readings, the glasses accurately track both position and orientation of the glasses through space [5].

NRSDK package is Nreal's platform package for developing mixed and augmented reality for Nreal glasses. The package enables Nreal glasses functionalities and provides Mixed Reality (MR) and Augmented Reality (AR) features. The core features are spatial computing,

optimized rendering, and multi-modal interactions. The package enables full use of spatial computing and gives the developer easy access to all its abilities. Optimized rendering is automatically applied to the applications to minimize latency, reduce judder, and enhance user experience. The package also contains an example project that shows all Nreal glasses capabilities and provides the developers with example code. The written documentation only provides with tutorials on some of the features of Nreal glasses and are not written in depth. Because of the scarce documentation, the developers had to go through the examples given and inspect the packages core scripts that contain the code with all the functionalities written. NRS SDK supports the development environment of Unity 2018.4.X and above [5].

Scrcpy application enables control of Android devices connected via USB or TCP/IP. It displays the screen of the device and enables interaction on an intuitive level. The application requires at least Android version 5.0 or API level 21 to work and is nonintrusive, i.e., nothing remains installed on the Android device, in this case Nreal computing unit [6]. This application was used for installing the developed application on to the Nreal computing unit.

Nreal's various features provide a different approach to user interactions. The user is placed in the real-world but can simultaneously interact with virtual elements. By merging virtual and real-world elements, it becomes possible to fill in the gaps of physical reality with digital enhancements, resulting in a complete and immersive experience. Plane detection provides the ability to place objects on detected flat surfaces in the real-world. Combined with 6 degrees of freedom, the user can easily walk through the real-world while looking at virtual objects through the glasses. This feature could be used for educational purposes, interior design, or general visualization of inaccessible objects. Image recognition can be used for educational purposes, museum tours and even advertisement. Hand tracking feature significantly changes user experience because it provides a simple and intuitive interaction with virtual objects. This feature can be combined with any other feature to expand on the user experience by making it more engaging and immersive. Hand tracking is best suited for education and simulations of jobs that require a hands-on approach.

B. *Ultraleap*

Ultraleap was formed when Leap Motion and Ultrahaptics came together in May 2019. Built for research and development, the STRATOS Explore development kit, which is used for development of TouchSpace serious game, is ideal for exploring how mid-air haptics can enhance innovative products and experiences. Particularly suitable for automotive, appliances/smart home, kiosks, gaming and computing applications. It consists of two parts, the Leap Motion Controller and Ultrahaptics. The Leap Motion Controller is a sensor that tracks hand movements, while Ultrahaptics projects tactile effects using ultrasound. Some of the tactile effects in mid-air that Ultrahaptics can project are virtual buttons and sliders, haptic pulses and alerts, immersive sensations such as textures, and presence for virtual objects, surfaces and

shapes, magical sensations such as lightning, fireballs, ghosts, clouds, bubbles and force fields [7].

To start Ultrahaptics and Leap Motion Controller, it is necessary to download suitable drivers for connecting the device to the computer (described in the chapter Development process, subchapter Implementation, third paragraph). After installing the driver, the device must be physically connected to the computer. Ultrahaptics needs to be connected to its charger, and it needs to be connected with a USB cable to the computer before turning on the switch on it. The Leap Motion Controller also needs to be connected with a USB cable to the computer before launching the application. To start using the application and Ultraleap, the user should place his hand above the Leap Motion Controller and Ultrahaptics at a height of approximately 20 cm. After the sensor recognizes the hand, the hand (in 3D form) and its movements will be displayed on the screen, and the user will feel ultrasonic waves on the hand in the form of a light breeze.

Ultraleap technology controls ultrasound waves to project tactile sensations onto your hand, without the need to wear haptic gloves or use hand-held game controllers. It is completely hygienic and it improves gesture control, making the user experience more engaging and immersive. Ultraleap can be used in education, it could help students to learn shapes, textures and movements, such as the movement of tectonic plates. It also helps visually impaired people to feel objects they cannot see.

C. *Virtual reality – Meta Quest 2*

Meta Quest 2 is a virtual reality set made by tech giant Meta, formerly known as Facebook. It is a successor of Oculus Quest, former virtual reality set made by Oculus. Meta Quest 2 set consists of virtual reality glasses and two controllers, one for each hand. Glasses have four built-in infrared cameras that track the room, controllers, and hands. Tracking the room is important for creating guardian. Guardian is an area created in the room in which is player free to move. Tracking controllers is used for showing the controllers in virtual reality in same position they are in real space. Hand-tracking technology is used to interact and play using the user's own hands. The Meta Quest 2 glasses have a high screen resolution and strong hardware that enables a virtual reality experience without the need for a computer or console. The glasses have a resolution of 1832 x 1920 pixels per eye and a refresh rate of 90Hz, which makes visuals in virtual reality clean and smooth. It also has 6 degrees of freedom (6DoF) which enables more precise and accurate tracking of the user's movements. The Meta Quest 2 also has a feature called Quest Link, which allows the wearer to wirelessly connect the glasses to a computer and play virtual reality computer games. This feature requires a compatible computer with a high-quality Internet connection [8].

On the right side of the glasses there is a power button, volume buttons and a USB-C port for charging. The device also has built-in stereo speakers and a microphone, as well as a 3.5 mm audio jack for users who prefer to use their own headphones [8].

The device comes with two controllers, Oculus Touch, which are designed to imitate the movement of the user's

hands in the virtual world. Controllers have numerous buttons and sensors that allow the user to interact with objects and perform a wide range of actions in virtual reality. Each controller has two buttons on the top, one on the side and a trigger on the back. The buttons on top are labeled A and B on the right controller and X and Y on the left and are used for various interactions. The button on the side is used to access the battery. The controllers also have several sensors that allow tracking the movements of the user's hands, including a gyroscope, an accelerometer, and a magnetometer. These sensors allow the controllers to detect the movements of the user's hands and translate them into actions in the virtual world. The controllers are wireless and have a very long battery life. They are designed to be intuitive and easy to use, allowing the user to interact with the virtual world as naturally as possible [8].

Virtual reality enables the creation of a completely new, virtual world in which the user has a 360-degree 3D view. Because of this it is best suited for visualizations and simulations for educational purposes. It is ideal for games where the user stands in one position or games where the player moves using teleportation. The ability to track the movement of the controllers in the real-world provides a more immersive usage than traditional console controllers.

D. Unity

Unity was the logical choice of platform because of its support for 3D video games, with a lot of built-in functions for VR. The Oculus XR plugin was used to connect Unity and the controller. It provides support for hand tracking and motion controls, as well as the ability to use the Meta Quest glasses' built-in cameras to create augmented AR experiences. It also allows developers to use Quest's advanced features such as 6DoF and hand gesture recognition [9]. Unity version 2021.3.11f1 was used for development of SolARsys. Unity version 2021.3.13f1 was used for development of UniVRse and version 2019.3.13f1 for development of TouchSpace.

Unity is a cross-platform technology developed by Unity Technologies, first announced and released in June 2005 at Apple's Worldwide Developers Conference. Since then, it has been gradually expanded to support a variety of desktop, mobile, console and virtual reality platforms. It can be used to create three-dimensional (3D) and two-dimensional (2D) games, as well as interactive simulations and other experiences. In Unity, it is possible to develop applications in the programming languages C# and C++. As part of this project, all three serious games were developed in C# [10].

III. DEVELOPMENT PROCESS

This chapter describes the application development process. Each subchapter represents one stage of development, and there are four in total. The first phase of the project included the formation of a team and familiarization with the project task. The students' task in the second phase was to get to know the given technologies and explore their possibilities. The third and longest phase

was the application implementation phase. The last phase was presentation of the created applications to the cadets of the Croatian Military Academy and to the initiators of the SPARK project.

A. Team forming

First phase of development process includes getting to know the team, familiarization with the project task, selection of the team leader and division into sub-teams (one team for each technology, i.e., serious game development).

B. Exploring technology and its possibilities

The second phase lasted a total of four weeks. At the beginning, the obtained devices (AR – Nreal Light Developers tool kit, STRATOS Explore development kit, VR – Meta Quest 2) were tested and the team members got acquainted with the possibilities of the technologies. After that, there was the launch and presentation of demo applications in between using the Unity system for each device. After that, the content of each serious game was defined in accordance with possibilities of its development technology (more about the content of serious games is described in section IV.). After the work was distributed among the members of the sub-teams, the implementation phase followed.

C. Implementation

The third phase lasted for ten weeks. Weekly meetings were held on which the features and functionalities of each product, i.e., serious game, were defined and/or tested. The development of each product was agile which means that requirements and solutions were incrementally improved between meetings. Sub-teams tested each other's products, commented on user experience and suggested improvements. This way mistakes were discovered and fixed much earlier during the development and the product was more flexible for content and user experience corrections. All sub-teams implemented their core features and functionalities very quickly and at the beginning of the implementation phase. The rest of the phase was spent on polishing the user experience and fixing minor problems that were discovered during continuous testing.

Nreal sub-team parallelly developed the Meet the Universe mode and Recognize the Planets game. The first iteration demonstrated the idea behind the application and its parts. Next iterations focused on implementing the main functionalities and user interactions. There were slight problems with the hand tracking feature, but after its resolve, the rest of the iterations focused on user experience and instructions. In those later stages of the implementation, testing and reactions from other team members were very important. Their feedback and suggestions helped in building better user experience.

To start Ultrahaptics and the Leap Motion Controller, it is first necessary to download the appropriate drivers for connecting the device to the computer: Ultrahaptics SDK (for Ultrahaptics)¹ and V2 Desktop SDK (for Leap

¹<https://developer.ultrahaptics.com/>

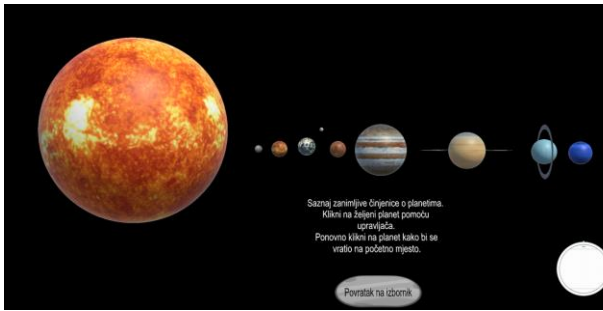


Figure 3 SolARsys: Mode „Meet the universe“

Motion)². The version of Unity compatible with the mentioned drivers is Unity 2019.3.13f1.

The VR team implemented the application collaboratively using Plastic SCM. The team initially had problems building the application and running it on VR glasses. Once that problem was fixed, it was challenging to connect the functionality to the Oculus Touch controllers since it was the first time the developers were doing it. Apart from the above, the team did not experience any major problems in implementing the application.

D. Presentation

The applications that were developed were showcased to the cadets of the Croatian Military Academy, who received the opportunity to explore all the features and possibilities that they offer. The cadets were highly impressed with the innovative and user-friendly design of the applications and were eager to make the most of them.

Additionally, the creators of the applications also presented them to the initiators of the SPARK project. The initiators had the opportunity to try the developed applications. They discussed their potential improvements and applications, especially in working with children. During this discussion the idea of these applications and technologies being available in the observatory for the visitors to play with and learn something new while they wait for their turn in the observatory arose. The initiators were extremely satisfied with both the implemented applications and the possibilities offered by new technologies.

Overall, the presentation of the applications to the cadets and the SPARK project was a successful and productive endeavor that generated enthusiasm and positive feedback.



Figure 2 TouchSpace: Main menu

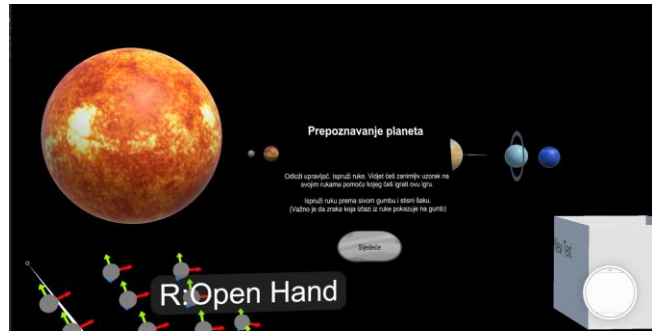


Figure 1 SolARsys: Game „Recognize the planets“

IV. PRODUCTS DESCRIPTION

This section describes three serious games - SolARsys, TouchSpace and UniVRse. SolARsys uses augmented reality technology, TouchSpace uses Ultraleap technology, and UniVRse uses virtual reality technology. The ways of using these three applications are also described. The images in this section contain texts in the Croatian language since all applications were created for use exclusively in Croatia.

A. SolARsys

When the application opens, the main menu is displayed, and the user has the option of selecting the Meet the Universe mode or Recognize the Planets game. The desired mode is selected using the Nreal controller.

By selecting Meet the Universe, the planets and instructions for interactions are displayed in front of the user (Figure 2). The goal is to learn interesting facts about the planets of the Solar System. The interactions with the planets are achieved with the Nreal controller. The user sets the pointer on the desired planet and presses the button on the controller. The selected planet will move closer to the user. On the left side of the planet an information panel will be displayed containing information about the planet. By clicking on the planet again, it returns to its original position and it's possible to select the next planet. The user can return to the main menu at any time by pressing the Back to Main Menu button.

Recognize the Planets game examines if the user has learned how to recognize each planet of the Solar System. After selecting the game, instructions are shown which explain to the user how to master the hand tracking functionality (Figure 4). The user must first put down the

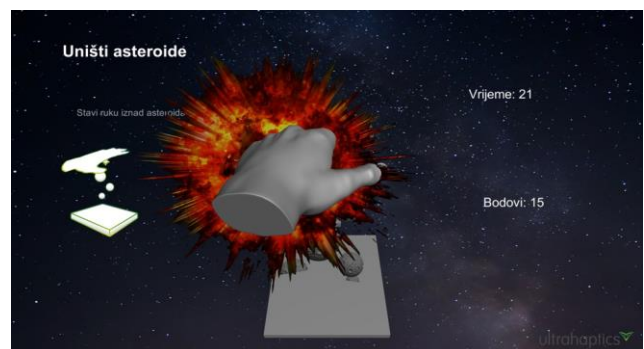


Figure 4 TouchSpace: Game „Destroy Asteroids“

²<https://developer.leapmotion.com/>

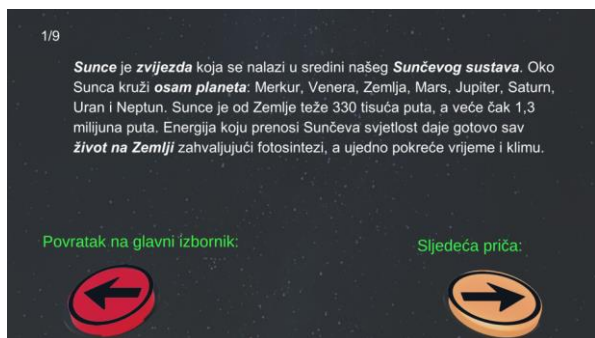


Figure 6 TouchSpace: Screen with informations about Sun



Figure 5 TouchSpace: Display of planets after the correct answer to the question asked as part of the quiz

Nreal controller, read the instructions and test the hand tracking functionality to get familiar with it. The hand tracking functionality recognizes when the users palm is opened or closed to form a fist, and with these gestures user selects the desired elements through the game. To select a button in the instructions, the user must extend their hand with the palm towards the button, and when the pointer coming out of the palm is on the button, the user must squeeze their hand into a fist. After the user has gone through the instructions the game begins. In front of the user is the Solar System, and on the right side is a box with the name of the given planet. The goal of the game is to recognize the planet of which the name is displayed on the box and drag the planet into the box. For the user to select a planet, they must walk up to it and form a fist as though they are grabbing an object in the real world. The user must keep his fist clenched to hold the planet and move their hand slowly to move the planet. When the user has placed the correct planet into the box, a new planet name is displayed. After the user has successfully identified three assigned planets, the game ends and a panel appears with the options to replay the game or to return to the main menu.

B. TouchSpace

At the very beginning of using the application, the main menu of the application will be displayed on the screen (Figure 2). The hand should be placed at a distance of approximately 20 cm above the Ultraleap. When the hand is correctly positioned, the hand model will be also visible on the screen. In the main menu it is possible to choose between three modes, each mode is represented by one button and corresponding color from the legend. Mode on the left (the green one, first button) is for learning about asteroids, mode in the middle (the orange one, second

button) is for learning about planets, and the last mode on the right (the red one, third button) leads to a quiz about planets. To enter one of the mentioned modes, it is necessary to press the appropriate button with a hand gesture (with an outstretched fist).

Before describing the modes, it should be noted that the return to the main menu of the application is possible in every part of the application by selecting the space bar, while the application is closed by pressing the escape key.

Selecting the first mode (the green button) in the main menu opens a screen with information about asteroids. After learning about asteroids, it is possible to play the game "Destroy Asteroids" by selecting the orange button with a right arrow on the same screen with the previously described hand gesture. As soon as the screen on which the asteroids are moving upwards is shown, it is necessary to use a hand gesture to destroy as many asteroids as possible within 30 seconds in order to protect the Earth. While playing the game, points are displayed on the screen (the number of destroyed asteroids). After the playing time expires, the final number of points is displayed on the screen. On the newly displayed screen, it is possible to return to the main menu by pressing the red button with a left arrow.

Selecting the second mode (the orange button) in the main menu opens a screen with information about the Sun and the planets of the Solar System. Return to the main menu is enabled by pressing the red button with a left arrow, while getting to know the next planet is enabled by pressing the orange button with a right arrow.



Figure 7 UniVRse: Display of planet name



Figure 8 UniVRse: Instruction panel

Selecting the third mode (the red button) in the main menu opens a screen with a planet quiz, i.e., a question about the Sun or a planet of the Solar System. Below the question, there are four answers marked with the letters A, B, C and D. Depending on which answer you think is correct, you need to select the button with the corresponding letter using the same hand gesture as in the rest of the application. If the selected answer is incorrect, it will be possible to answer the same question again. When the chosen answer is correct, the planet to which the question was related will be displayed on the screen as a reward. It is possible to touch the displayed planet and "pass through it" with the appropriate hand gesture above Ultraleap. You can return to the main menu by pressing the back button (the red button with a left arrow).

C. UniVRse

UniVRse game, when started, puts the player above the Sun. While floating above the Sun, the player can enjoy a spectacular view of the universe. The player can also rotate 360 degrees and watch all the planets rotating around themselves and orbit around the Sun. For better orientation, the orbits of the planets are shown. The rotation and orbital velocity of the planets are scaled from actual velocities in universe. Size and distance from the Sun are also scaled, and the ratios are preserved. The only ratio that is not preserved is the size of the Sun, as it is disproportionately large compared to the planets to fit in the virtual reality environment. Using the left controller, the player can teleport to the planet by pointing the controller at the planet and pulling the trigger on the controller. While the controller is not pointed at any planets, the laser line coming out of the controller is red. The moment the controller starts pointing at a certain planet, the laser line changes color to white, and its name is displayed above the planet. When the player teleports to a planet, they will begin to move along with the planet through space. During this time, the player can observe the universe from that position above the planet. All the time, the player can press the Y button to see instructions for using the application. Also, pressing the X button shows interesting information about the planet the player is above, or about the Sun, if the player is above it.

V. CONCLUSION

The developed applications are a great addition to the observatory since they allow visitors to have fun and learn about the Solar System in an interactive way while waiting in line for stargazing through the telescope. Experiencing new technologies such as augmented and virtual reality, as well as haptic technologies, can not only make the wait more interesting, but also help popularize science, technology, engineering, and math (STEM) as children

and other visitors are introduced to the possibilities of these technologies in engaging ways as they prepare to observe space.

Each of the developed applications takes advantage of the technology for which it was made, and they also complement each other. So SolARsys uses augmented reality, allowing the user to see virtual planets in the real world, and learn about the Solar System and assess knowledge by recognizing planets. TouchSpace uses Ultraleap technology, introduces the user to asteroids and planets of the Solar System, tests learning through a quiz, and as a reward allows touching the planets. UniVRse is an application that, with the help of virtual reality technology, tries to give the user an idea of the Solar System and the mutual relations between the planets and the Sun.

Based on the enthusiasm of the cadets and project initiators for the applications, there is no fear for the popularity of STEM in small towns like Križevci, but also in the whole of Croatia.

The success of this project highlights the exciting possibilities for the future of education as technology continues to evolve and improve.

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