Software Prototype Based on Augmented Reality for Mastering Vocabulary

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Abstract – **Interactive experience of Augmented Reality that is created by deploying virtual objects in a real user environment, and its augmentation by audio-visual elements as well as the possibility of touch, provides added value for learning, especially regarding content multimodal presentation, increasing learner's motivation and level of engagement. This is very promising, especially in the field of education and rehabilitation, where current research slightly takes focus in this technological direction. To conduct this type of research, the prerequisite is to have a quality prototype with features, easy to understand and use by users of different cognitive skills, and yet sophisticated enough to carry out the research. The paper presents software prototype based on Augmented Reality aimed for mastering vocabulary for children with complex communication needs. The solution was developed in the multidisciplinary cooperation of students and teachers from the technical field and professionals from the education and rehabilitation field. The overall development process and initial evaluation are described, as well as the developed prototype from the technological and user perspective.**

Keywords – Augmented Reality; virtual objects; learning; education; rehabilitation; children; mastering vocabulary

I. Introduction

The use of Augmented Reality (AR) in education is still in early stages but shows great potential. The very purpose of AR is seamlessly blending digital information and entertainment with everyday surroundings, providing additional content to certain real-life problems without shutting out the real world. This makes it an excellent tool for learning, especially with today's younger generations who are being raised in a world dominated by smart devices. Everyday advances in digital technologies have had an impact not only on the way how children learn, but also on the way how children communicate with their family, friends, and peers at school. The advent of mobile touch-screen devices (e.g. tablets and smartphones) has also had an impact on the Augmentative and Alternative Communication (AAC) methods used to support the communication process of people with Complex Communication Needs (CCN) who also include children with motor, language, cognitive, and/or sensory perceptual impairments resulting in different developmental disabilities. Children with CCN may particularly benefit from using tablet devices with appropriate AAC applications because of its many advantages [1]. Despite the advances in AAC domain regarding technologies, researchers emphasize that future research and development is required around other technological innovations, including AR, that might improve AAC technology solutions for children with CCN [2]. Everything mentioned motivated members of ICT-AAC research group[1] which has been conducting intensive research in the AAC domain for over a decade and has developed over 30 AAC applications for most popular platforms, such as Android, iOS and Web[2], to conduct this type of research where the potential and possible benefits of AR-based solution for mastering vocabulary for children with CCN is explored.

To develop a functional prototype of AR-based software aimed for children with CCN to master the vocabulary, the multidisciplinary project was initiated. It involved students and teachers from the technical field and professionals from the education and rehabilitation field. Given the target user group, professionals from education and rehabilitation field were reached out to provide expertise and to evaluate the project's stages of development. The objective of the developed software prototype is to serve as a proof of concept, evolutionary prototype, and foundation for development of similar solutions or future upgrades, and for further verification of the applicability of such software by abovementioned professionals.

The paper presents developed software prototype from the technological and user perspective as well as the overall development process. Selection process for development environment is presented. Also, initial prototype evaluation of functionality, simplicity, design, usefulness, and technical quality of content is described, and the results are presented.

The rest of the paper is organized as follows: Section II looks into the principles of AR and its value in education, Section III gives a description of technology used for prototype development as well as development phases, Section IV describes the resulting prototype and its use, Section V brings the initial prototype user evaluation results, and, finally, Section VI concludes the paper.

II. Augmented Reality for Learning

Augmented Reality is an interactive experience of a real environment in which objects from the real world are complemented by computer generated information. In general, the additional digital information can be

[1] http://lab.ict-aac.hr/

[2] http://www.ict-aac.hr/index.php/en/applications

constructive, meaning it is simply added to the environment and is its continuation, or destructive, in which case it conceals and replaces our reality, be it just visually or through more senses. It is important to note the difference between augmented and virtual reality (AR and VR). Although they both lie on the so-called "reality-virtuality continuum", they do not present the same technological concept. While the technology of VR relies on destructive supplementation, with the purpose of blocking our real-world perception and placing us in a completely virtual world, AR makes use of constructive supplementation, working to add information about our surroundings and allow us to interact with the digital world without taking anything away from our perception of reality [3-6].

VR is commonly used in simulation software, video games and other entertainment products, and most often requires a VR headset with a display, speakers, and movement-tracking technology, possibly in combination with special remote controllers to be used. In terms of supported devices, AR is inarguably more versatile, with various implementations for smartphones and tablets, TV broadcasts, as well as AR-specific devices such as HUDs (head-up displays), HMDs (head- or helmet-mounted displays) and headsets (e.g., *Microsoft HoloLens*). There are many uses for AR today. Some have been evolving since the distant years of the Second World War, such as the aforementioned HUDs and HMDs that serve as digital aid for pilots and other vehicle crew members. Others are much younger but just as widespread, including special animations in TV broadcasts, control and guidance software in industrial plants, entertaining and informative smartphone applications, educational software, and even AR-powered computers such as the *Microsoft HoloLens* [4-5] [7-15].

Many interactive educational applications with AR elements can be found. The *Virtual Teacher* series' applications [3] includes AR applications for learning mathematics, physics, human anatomy, programming, and geography. *Octagon Studio* published the whole product line designed to make STEM learning simpler and fun with AR. With different sets of *4D+ Flashcards*[4], the users can learn about animals, space, dinosaurs, occupations, human anatomy, cars, history of aircrafts etc. from the facts and information in AR mode. Focusing on AR in educational software, several applications were studied more in-depth in the pre-development stage of the research to explore the established software requirements for similar products. *AR Anatomy 4D+*[5] is a free AR-based application used to learn about the human anatomy. It uses markers to display 3D models of organs or organ systems which can be interacted with. The products from the US company *Alive Studios*[6] that are designed specifically for use in classroom has also been examined. They utilize AR to educate students in several different fields, including reading and math. The individual applications also make use of markers to generate digital objects or trigger certain actions.

Overall, AR already has a large presence in mobile applications. Given the versatility of today's smart devices and the way AR can harness many of their existing elements, the mobile world on its own is a big playing field for this technology. Though the more complex interactions that exist famously in VR, such as hand tracking and hand gestures in front of a camera, are possible on mobile devices, there are still improvements to be made (though this will likely happen now that smartphones are being shipped with depth sensors and multiple-lensed cameras). That is why many applications use simpler touch commands or even voice recognition which are the interactions that most smartphone users are familiar with, and there is not a huge difference between typing a text message and clicking on models of distant stars that appear on your camera feed, as is the case in *SkyView® Lite*[7] and *Star Walk 2 Free - Identify Stars in the Night Sky*[8] applications. Just like hand tracking and gestures, visually processing a device's surroundings is still imperfect or simply too slow, so, to trigger certain actions or digital renderings, markers such as QR codes are still a popular way to track the "reality" part of "augmented reality" [4][16]. Nevertheless, environment scanning is used in a significant number of cases, such as the *IKEA Place* application[9].

III. DEVELOPMENT OF AR PROTOTYPE

The prototype development is based on an evolutionary model of the software development lifecycle, where the required prototype has been developed in several successive iterations. An evolutionary model involves continuous work with user representatives whose feedback on each product version can result in new features or functionalities for the next version. This development method is typical when working with new technologies. In this case, experts from education and rehabilitation field were the one who defined the requirements, i.e. features and design of an AR prototype. As mentioned before, the technical team involved students enrolled in the project and the main goal for this 3-month-project was to develop a functional AR solution prototype with features, easy to understand and use by users of different cognitive skills, and yet sophisticated enough to carry out the AR based research.

In the first phase of the project, that lasted for a week, the development team members and communication channels were defined. The second phase, with the duration of three weeks, mainly consisted of planning and choosing the right technology for the development. Because of its simplicity and accessibility, Unity game engine[10] (version 2018.4.14f) was chosen as a development platform for the prototype. Unity is used for compiling the project into an

[3] http://arkids.cards/en

[4] https://octagon.studio/products-and-services/4d-flashcards/

[5] https://play.google.com/store/apps/details?id=com.DanikTM.ARAnatomy

[6] https://alivestudiosco.com/

[7] https://play.google.com/store/apps/details?id=com.t11.skyviewfree

[8] https://play.google.com/store/apps/details?id=com.vitotechnology.StarWalk2Free

[9] https://play.google.com/store/apps/details?id=com.inter_ikea.place

[10] https://unity.com/

application for Android[11], which has been selected due to its leading market share and the project team's ability to test the application more reliably on a representative sample of Android devices. Unity offers a great range of AR software development kits (SDKs) to its users. The following SDKs were analyzed: ARCore[12], Maxst[13], Wikitude[14], ARKit[15] and Vuforia[16]. Maxst and Wikitude have both shown to be unacceptable, as it would take up to eight days to obtain a license for use. ARCore, ARKit and Vuforia were simple to set up, but there are some differences between them. ARCore is Google's, and ARKit is Apple's platform, which means that with these SDKs, applications can only be developed for Android or iOS devices, while Vuforia supports application development for both types of these devices. Every smartphone has a camera that supports the use of Vuforia and most importantly, Vuforia is marker-based. Markers are real-world images or 3D objects that Vuforia can detect and track and serve as a backdrop for AR (3D model, image, video, animation etc.). While scanning the space with a mobile device, Vuforia tries to detect markers by comparing the camera image with a database that contains all the markers used in the application. Once the marker is detected, Vuforia will monitor if it is at least partially in the camera's field of view. After reviewing and testing these SDKs, Vuforia was selected because it is easy to use and work with and it also worked very well with scanning markers which was necessary for our prototype. Smart Recorder (SmartMob)[17] application for recording sound and the default camera application on Android phones were used for creating audio and video content in the prototype (e.g. audio on the first level, video on the second level). The last technology that was used is Adobe Photoshop CC[18] for creating custom icons for the prototype (e.g. back button, info button etc.). All audio and video content, as well as the buttons in the prototype, were made by the student project team.

The third phase of the project, i.e. the implementation phase, lasted for ten weeks. Throughout the development there had been four versions of the prototype. The initial version of the prototype was an AR application whose main goal was to show the possible interactions in mobile AR, more specifically to show two types of content when scanning the marker. First option enabled the user to scan a predetermined marker after which a 3D object displayed over the same marker. Second option displayed a video (over the marker or in full screen mode) after the marker was scanned. This prototype version was shown to the experts from education and rehabilitation field, after which they filled out the prepared questionnaires and gave their feedback. This was the input for the next phase of the prototype development. Main functionalities that were defined based on experts' feedback are the following: the application will have three levels, each containing different AR content that is shown to the user upon scanning the marker. The next prototype version included implemented three levels for only one object defined for mastering vocabulary. Further direction of development was discussed through weekly meetings of students and teachers. The third version of the application, i.e. the alpha version, had implemented three levels of the application for all five objects the experts defined to be used for mastering vocabulary. The first level contains 3D models, the second contains videos and the third level contains a quiz after which the bonus level is unlocked if the user answers correctly to all questions in a quiz. For the user to access the content contained in each level, a marker needs to be scanned. The marker is placed somewhere in their environment, where the educational content is applicable. For example, the marker denoting educational content about the toothbrush should be placed in the bathroom, near the user's actual toothbrush. Using any level of the prototype, the device's camera view is opened, enabling the user to scan the marker designated for the desired object and view its educational content. The content used in the third version of the prototype was reviewed by the experts from education and rehabilitation field. The alpha version of the application was evaluated by students of the Faculty of Electrical Engineering and Computing. Firstly, they used the application and then they filled out a questionnaire in which they could grade each part of the application. Their feedback helped to upgrade the prototype and develop the fourth. i.e. the final version of the prototype, in which bugs were fixed and design improved.

The next step of the project will be sending the prototype application to experts who work with children with complex communication needs. This round of testing will be longer and more important than previous evaluations since the prototype will be in proper use with its target audience for a longer period. Using the first-hand feedback, the application can be further improved or adapted, and finally slated for public release.

IV. AR Prototype Description

When the user runs the application for the first time, the application requires the setup of a few options. The first option is to enter the user's name (i.e. a child's name who will be using the application). This step can be skipped, and the user's name can be set in the settings of the application. The second option is to adjust the theme of the application, i.e. to change the background and text color if better contrast level is needed for those with visual impairments (Figure 1). The last setup step is the option to enable or disable the in-application sound. After the setup, these options can always be changed in the settings menu (Figure 2). Besides the user's name, application theme and sound option, the user can access the description of the application via information button in the settings. Besides the settings button, the home screen of the application contains exit, information and play buttons (Figure 3). The information button on a home screen leads to all the markers that are used in the application, as well as the prizes won at the bonus level.

[11] https://www.android.com/

[12] https://developers.google.com/ar

[13] http://maxst.com/#/

[14] https://www.wikitude.com/

[15] https://developer.apple.com/augmented-reality/

[16] https://developer.vuforia.com/

[17] https://play.google.com/store/apps/details?id=com.andrwq.recorder&hl=hr

[18] https://www.adobe.com/sea/products/photoshop.html

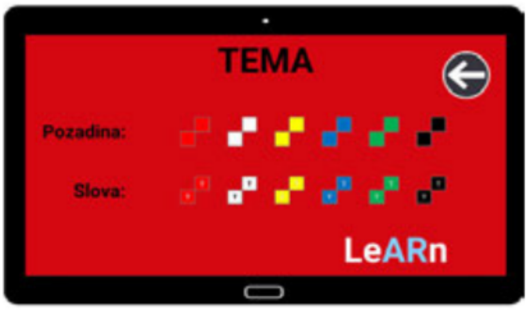

Figure 1 Setup of application theme

Figure 2 Settings screen of the application

Figure 3 Home screen of the application

The play button leads to a new screen where the user can choose one of the three different levels and read short information about each level (Figure 4). The fourth (bonus) level can be reached from the prizes button on this screen, too. On the first level, after scanning one of the five different object markers, a 3D model of the scanned object is shown on the marker in the real world (e.g. after scanning the toothbrush object marker, a 3D model of a toothbrush appears on the marker like it is showed in Figure 5). Also, an audio recording is played with a short description of the scanned object. After scanning one of the object markers on the second level, a new screen with a play button is shown which can be selected to play an informative video about the scanned object. In the video, the child can learn the purpose of the object and how to use it (Figure 6). The video can be paused and played again once it is over. By pressing a button for the next level, the third level screen is shown. The third level is a 3-question quiz about the scanned object. The quiz starts by scanning one of the object markers. After scanning the marker, a question appears on the right side. To answer a question, the user clicks on an eye button to reveal a camera window on the left after which the user scans the "yes" or "no" answer marker (Figure 7).

Figure 4 Application screen with three levels, prizes, and levels information buttons

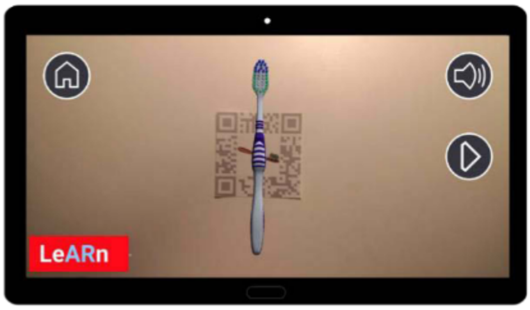

Figure 5 3D model on the object marker

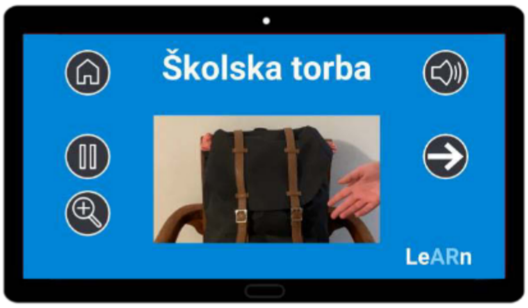

Figure 6 Informative video about the scanned object

If the question is answered correctly, the next question is shown. If the question is answered incorrectly, the same question is shown repeatedly until it is answered correctly. After answering correctly to all three questions about an object, a new 3D model is unlocked as a prize to be used in the bonus level. Once the prize for an object is unlocked, the child must scan the same object marker on the bonus level, and they will be able to see their prize object (Figure 8).

Figure 7 The quiz screen of the application with the exemplary question

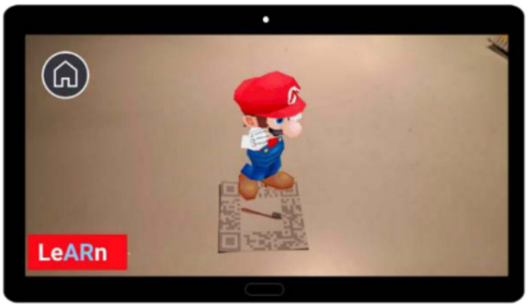

Figure 8 Prize model shown on the marker in the bonus level

V. AR Prototype User Evaluation

In this section, the questionnaire is described used for evaluation of functionality, simplicity, design, usefulness, and technical quality of content used in the prototype. The questionnaire consisted of seventeen questions and was fulfilled by student population outside the project. Sixteen out of seventeen questions had answers in the form of a *Likert scale*, i.e. statements that could be rated from 1 to 5, 1 being 'strongly disagree' and 5 meaning 'strongly agree'. The first five questions were based around the simplicity and functionality of the prototype. Other questions determined the quality of the content used, and lastly if the prototype has a clear and interesting use. Fourteen participants answered the questionnaire in time for the evaluation. Table 1 shows sixteen questions used in the user satisfaction questionnaire and average mark calculated for each question.

TABLE I. USER SATISFACTION QUESTIONNAIRE AND AVERAGE MARKS

No	***Question***	***Avg. mark***
1	The purpose of the application is clear.	4.64
2	The application was easy to use.	4.43
3	Navigating through the application was intuitive.	4.21
4	The application has no technical flaws.	4.14
5	The application design is suitable for target users – children	4.71
6	The order of levels of different difficulty is appropriate.	4.57
7	The use of markers for each level is clear.	4.93
8	The 3D models that appear on markers are appropriate, considering the purpose of the application.	4.86
9	The narration in the application is comprehensible.	4.71
10	The narration in the application is educational.	4.57
11	The videos in the application are comprehensible and educational.	4.86
12	The questions in the quiz are useful and appropriate.	4.07
13	The bonus level is a good incentive to use the application.	4.29
14	The use of AR enhances the user experience.	4.71
15	The application was interesting to use.	4.36
16	Overall, I am satisfied with the application.	4.29

The results showed an overall positive feedback, with few neutral answers. When asked if the purpose of the prototype was clear, 85,7% of students gave the highest grade, or they 'strongly agreed'. When asked about the ease of design and use, on average 48,23% of the students 'strongly agreed' and 42,88% of the students 'mostly agreed' with the rest giving neutral answers. In the second part, 65,18% of the students 'strongly agreed' when asked about the functionality of the prototype and practical use in targeted groups of users, 28,8% 'mostly agreed' while the rest gave neutral feedback. In the final part, where the students were asked if the prototype was interesting and their overall impression, feedback consisted of 47,6% students answering, 'strongly agree', 50% 'mostly agree' and only a small percentage of neutral answers. This questionnaire mostly helped with fixing bugs and design or navigation flaws since the evaluators are not the targeted users for the prototype. The evaluation with rehabilitation and educational experts is next step that is currently in the progress.

VI. Conclusion

Today's high technology provides numerous opportunities for creating educational content for all generations. It can contribute to the creation of an interesting solutions that enables and encourage the communication process, not only for children with developmental disabilities or CCN, but also for typically developing children. When it comes to AR which implies an interactive experience of a real environment, the impact of using it cannot be negligible. The AR-based software prototype aimed for mastering vocabulary for children with CCN provides insight into the phases that are necessary to be followed and implemented in the developing process of the software prototype based on augmented reality. The multidisciplinary approach is one of the most important preconditions in the process of developing high tech solutions designed for children with CCN. The developing process based on the project form approach consist of the following phases: defining the project team members, defining the channels for communication, planning, choosing the technology and developing phase – different kind of versions were tested before the final one was developed. The development of such solutions implies a significant investment of time and human resources in the context of inputs of experts from various fields. Described software solution indicates that the possibilities of a joint action - including students and professionals from different research fields could be very productive and socially responsible. The developing process described in this paper with the accent on the multidisciplinary approach, besides good practical example related to the development process in the field of augmented reality, can also serve as a strong motivation base for all students and their mentors working together.

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