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GeoAR - An Augmented Reality Application to Learn Geography

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Abstract. Over the last years, augmented reality was used in various domains, from medical, industrial design, modeling and production, robot teleoperation, military, entertainment, leisure activities to translation, facial recognition, assistance while driving, interior and exterior design, virtual friends, Internet of Things and eLearning. In eLearning, the combination between classical and augmented content (the later coming with 3D models, images, sounds, animations, Internet browsing, etc.) can help the teacher to better explain the content of the courses. GeoAR application was created with the purpose to learn more things about the geography of Europe (countries, capitals, flags and neighbors) in a different and more attractive way. We know that new technologies draw children's attention, and that's why we used the Augmented Reality feature in developing our application. Using GeoAR, children can play a game and learn at the same time. Thus, learning geography becomes more interesting and exceeds the traditional way.

Keywords: Augmented reality (AR), eLearning, Unity, Geography.

1. Introduction

Mixed realities have been used in education for a long time (Munnerley et al., 2012): the augmentation of wall paintings in caves is an approach to the transfer of knowledge about hunting and survival; Heilig's patent for Sensorama describes the need for a solution for teaching, training and educating people in armed forces, industries and schools (Heilig, 1962); Ivan Sutherland saw the augmented image as a solution to give the user a "chance to get acquainted with concepts that cannot be achieved in the physical world" (Sutherland, 1965); and the pioneering activity of Caudell and Mizel in Boeing's augmented reality were designed to teach workers how to assemble complex components into aircraft (Caudell and Mizell, 1992).

Large-scale applications for AR in education were impossible before recent releases of cheap and affordable smartphones and tablets and before the emergence of software that allows the development and experimentation of real world augmentation. Opportunities to exploit AR technologies in education are now growing, while mobile hardware is proliferating, and access to the Internet becomes universal (Arusoaie et al., 2010). Augmented reality is starting to take a big role in training people in different areas like surgical assistance, equipment maintenance, car repairs, behavioral changes, architecture and urban and environmental education (Forsyth, 2011).

Applying AR in an educational context equals to using "technology to add virtual objects to real scenes, by adding missing information to real life" (El Sayed et al., 2011). As one can see, the emphasis is on providing additional information, such as a type that may be missing or inaccessible to students in the real world. Teaching anatomy, which requires a considerable amount of effort, expertise and temporal resources, is an example where AR can be used effectively to provide additional information (Blum et al., 2012). In artificial intelligence augmented reality can be used to show what are the steps executed by an algorithm based on a Greedy paradigm (Păduraru and Iftene, 2017). Our GeoAR is other example of AR application.

One of AR's most significant features in terms of pedagogy is that it offers a student-oriented and flexible space to provide learning opportunities. Learning is taken away from traditional spaces (such as classrooms, amphitheaters, laboratories) and follows the students wherever they are. Learning opportunities can be present, for example, at home, at the workplace, in public transportation – and can be taken everywhere or can be transferred to anyone. As AR develops more about interactive applications, students can become critics and co-creators, leaving behind a record of their learning the specific artifact or the place they have met (Billinghurst and Dünser, 2012).

AR does not come as a revolution: AR will not replace the existing pedagogical paradigm with a new world based on high technology. Instead, the pedagogical past is a rich resource for the future. The work of (Mishra and Koehler, 2006) highlighted the importance of understanding the nuances between content, pedagogy and technology in designing learning environments. The model they propose, TPACK, highlights the dynamic interaction between these three areas.

Today, augmented reality is one of the most used technologies in games and applications that are based on the concept of educational software (Johnson et al., 2000), (Munnerley et al., 2012), (Pînzariu and Iftene, 2016).

This area increases the curiosity among both children and adults with innovations that change the classical learning system (Iftene and Trandabăț, 2018).

Nowadays, children are not motivated to learn in a traditional way because they have a lot of energy and they can't focus on reading paper-based materials, such as books. GeoAR uses augmented reality in the learning process and then offers the opportunity to test and deepen the knowledge acquired in the memory branch with a game full of different questions. Using this software, children learn geography by playing a game which makes the whole learning process more interesting.

The essential elements of the creation and usage of the application are presented in the four sections of this paper. The following section includes a brief description of existing software which uses the augmented reality with educational purpose. For each selected branch, augmented reality manages to attract more users and to give them the opportunity to learn new things easily

Section three highlights the architecture and software implementation, resources used and problems that we encountered during the integration of all modules, but with their solutions. The last sections of this paper focus on the evaluation of the system and on conclusions of the paper.

2. AR applications used in eLearning

The next four examples of applications underline the idea that education would develop more if they start to use applications of this type during classes. In primary school, children are often losing interest in the lessons. They get bored and find another occupation. To catch their attention we can use activities that are including new technologies.

2.1. Fetch! Lunch Rush

App Fetch! Lunch Rush[1] is inspired from a TV series for children with a dog presenter named Ruff Ruffman. It is a multiplayer game where the user has to help Ruff with the lunch orders of his/her colleagues that are preparing a new film. The challenge is to keep track of the number of sushi pieces that the crew wanted (see Figure 1).

[1] Fetch lunch rush: http://pbskids.org/apps/fetch-lunch-rush.html

Figure 1. Example of using App Fetch! Lunch Rush[2]

2.2. Anatomy 4D

Anatomy 4D[3] and the printed pictures are a helping tool for students, teachers, doctors and others who want to learn about anatomy and also want to have an interactive experience with a 4D representation of the human body. 4D Anatomy uses augmented reality and other technologies in creating educational software for the 21st century. The application takes viewers on a journey inside the human body and the heart, revealing the spatial relationships of organs, skeleton, muscles and body systems. This three-dimensional learning environment is easy to use and can be used in every classroom (see Figure 2).

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[2] Adweek: http://www.adweek.com/digital/pbs-kids-fetch-lunch-rush-brings-augmented-reality-to-1st-2nd- grade-math/
[3] Anatomy 4D: http://anatomy4d.daqri.com/

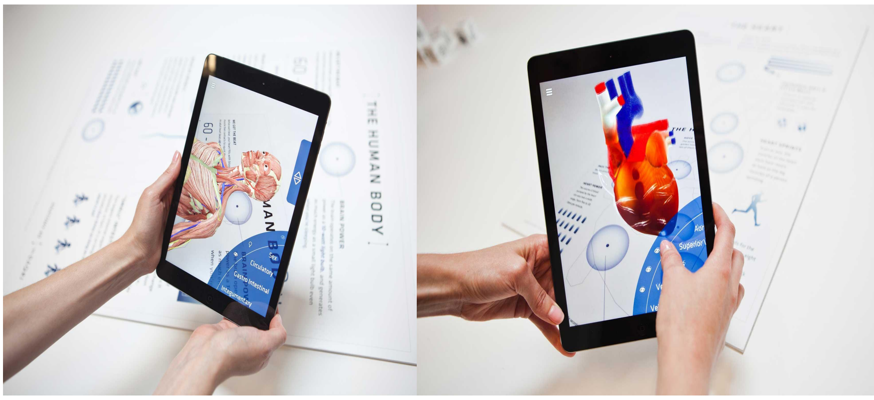

Figure 2. Viewing the human body[4]

2.3. Geometry 101

Geometry 101[5] is an application that helps the user to study the geometric solids with their properties and calculation formulas. Thanks to augmented reality we can explore in different ways various geometric structures.

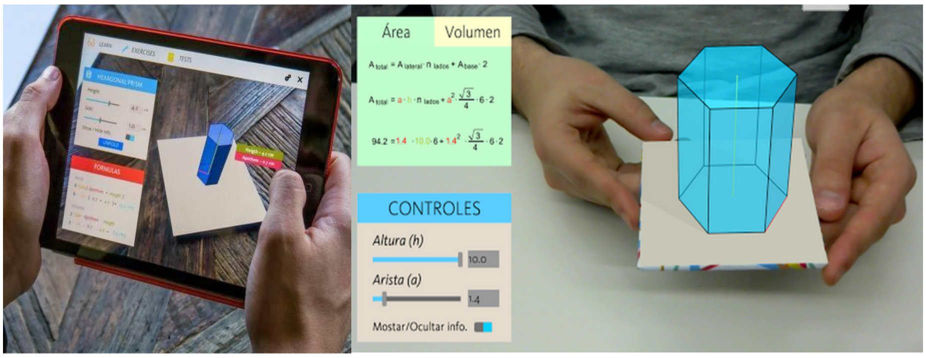

Figure 3. (left) Geometry 101 app on iPad[6], (right) formulas for area[7]

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[4] Anatomy 4D: http://anatomy4d.daqri.com/
[5] Geometry 101: https://play.google.com/store/apps/ details?id=sk.geometry&hl=ro
[6] Geometry 101 iPad: http://www.twoguysandsomeipads. com/2014/02/zientia-changing-way-we-learn-with.html
[7] Geometry 101 Formulas: https://edshelf.com/tool/geometry101/

2.4. Star Walk 2

Clear summer night is a good time to see the stars in the sky, and by using the Star Walk 2[8] we can learn more about them. Star Walk 2 is not only about discovering constellations, but also about exploring each planet separately. In this case, we can find specific information such as: distance to the Sun, temperature, visual dimension and other. If you give permission to access the phone's camera, we can see using augmented reality where the stars are positioned in relation to the phone, as shown in Figure 4.

Figure 4. Seeing stars by using the Star Walk 2[9]

3. Proposed solution

The GeoAR application helps pupils in secondary school to learn the geography of Europe (countries, capitals, flags and neighbors). The printed maps accompanying the mobile software do not contain written information (such as neighbors and country names), but just the contours for each country

[8] Star Walk 2: https://play.google.com/store/apps/details?id=com.vitotechnology.StarWalk&hl=ro

[9] Star Walk 2 Apple: http://www.iappsclub.com/2015/07/star-walk-2-is-apple-free-app-of-week.html#.WUmcqu3yjIU

(these are actually the markers used by our application).When we look at the maps through the phone's display, we see them filled in with the name of the country, along with the flag, capital and neighbors (Figure 6). If the user wants to save the country map with its flag, this is possible with the extra feature of the application. This can be done by producing an image with the printed map and the country's name and flag positioned above, depending on the user's preference (he can enlarge/shrink and re-position overlapped objects).

The main activities of the application are shown in Figure 5. All activities must be entered in the file *AndroidManifest.xml* to work properly. If an activity is used but it is not listed in this file, the application closes when we want to access it.

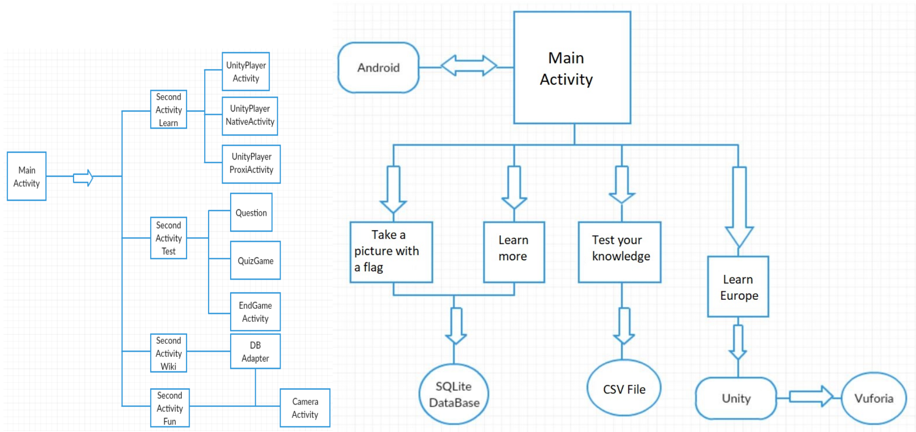

Figure 5. The main activities of the GeoAR application

The application has three important modules:

- The *Learn Europe* module - was mostly made in the Unity, interface that allowed to use the Vuforia Development Kit. The project exported to Android Studio has packaged the functionality provided by Unity and Vuforia in several libraries. With the help of JNI Android technology, it was easy to make links between libraries and Java code.
- The *Find out more* module - has the functionality to redirect the user to the Wikipedia page of the country they select. If the user wants to know more about a country in Europe, there is no need to search on Google, but it can be done through the app. An internet connection is

required and a single push. We also introduced a filter to find the country easier.

- The *Test Your Knowledge* module - As each piece of information you want to keep is tested, this module deals with these tests. The created game aims to test the user about the information presented in the learning part. Questions and variations of responses are read from a configuration file and mixed every new run to raise the difficulty level.

During the development of the application, following the discussion with the teachers, we came to the conclusion that the idea of teaching pupils new things through a game is good enough because they will memorize some things without being aware of the effort they made. They will play a game and they will have to retain as much details as possible to be the best players. Also, the test and knowledge assessment component is not a stress and emotional component as a written test or as an oral evaluation.

In this section we will present details of the system architecture and key modules of the application. The four main features are: *Learn Europe, Find more, Test your knowledge* and *Take a photo with a flag*. For each, we have included what technology we used during the project. Below we will detail the implementation characteristics for each module.

3.1. Learn Europe

Creating this module is based on augmented reality. The module corresponds to the *SecondActivityLearn* in Figure 5. After completing the steps with Unity[10] and Vuforia[11], we exported the project in Android Studio. Exported files contain scripts in C # corresponding to the steps that we made in the Unity interface and libraries necessary for the project to remain unchanged when it will be imported into Android.

This part of the application was developed mostly in Unity because it allowed to use Vuforia Software Development Kit. Initially we had some problems with the compatibility of the two technologies, but after the update of the latest version for Vuforia problems were solved. Producers were able to provide compatibility between Unity and Vuforia to facilitate the development of augmented reality applications.

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[10] Unity: https://unity3d.com/

[11] Vuforia: https://www.vuforia.com/

The exported project from Android Studio has wrapped some functionality provided by Unity and Vuforia in several libraries from jniLibs directory. The bound between the libraries and the code written in Java was easily done with the help of Android JNI.

The printed maps, accompanying the mobile software, do not contain written information (such as neighbors and country name). They show only the outlines for each country. They are also meant to be marker images for the augmented reality part. When we look at the maps through the phone's display, we can also see the country's name, flag, capital and neighbors (see Figure 6). Image recognition is performed more quickly if there is good light, especially with natural light.

To see how it works we should follow some steps:

1. Firstly, we should open the application at *Learn Europe* module.
2. Then we will open the book with printed maps to a page of our choice.
3. We will look at the maps using the phone camera. From this moment, with augmented reality, we will be able to see different items associated with the maps (see Figure 6).

Figure 6. *Learn Europe* module is based on augmented reality

3.2. Learn more

If you want to know more about a particular country, the application guides you to the Wikipedia page which contains more information (such as: hymn, population, history, sights and more) (see Figure 8 in the right). This way, if the user wishes to learn more about a country in Europe, it is no longer necessary the search on Google, because it can be done in the application, but it requires Internet connection and a single tap. We also introduced a filter to find the country more easily (see Figure 7 in the left). To send the name of the country from one activity to another (switching is done with Intents) we will use the country's name retrieved from the database (with some changes in some countries to match the correct page from Wikipedia).

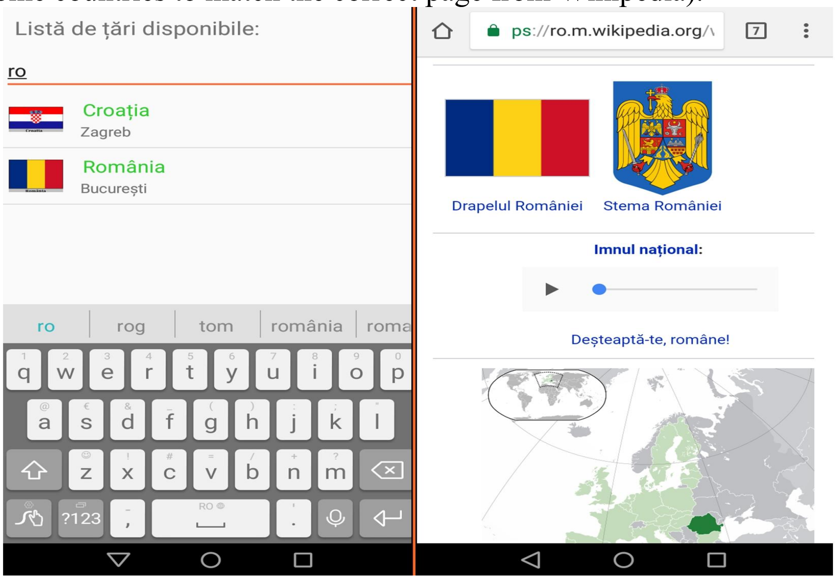

Figure 7. *Learn more* module

3.3. Test your knowledge

This module has the purpose to test what information was kept in mind during the learning process. The created game tests the user with the information found in the learning process. When we use this module, we assume that the user has gone through the learning module. The knowledge gained can then be tested in this module. The database has several questions. Figure 8 illustrates three of them, two with the correct answer (in the left and in the right) and the other one with the wrong answer (in the middle).

Figure 8. Test your knowledge module

In order to have different levels of difficulties, some answer options include the most common confusions that you can make. For example, the flag of *Andorra* resembles the flag of *Romania* and the one of *Republic of Moldova*. Thus, in the variants for picking the answer, we introduced the two confusing variants in addition to the correct answer. Many questions have response variants that are meant to mislead if one is not very familiar with all the details, making the game even more exciting.

3.4. Take a picture with a flag

The module was created with the scope of remembering the name and capital of a country, seeing only its outline in a picture. That picture is saved locally and it is easy to find. This feature comes as an extra part of the module Learn Europe. Also, it can be used when you want to take a picture and specify the country name in it. For example, when we go on a trip and we want to send to a friend a picture with a tourist attraction and the country name on it (see an example in Figure 9).

Figure 9. *Take a picture with a flag* module

4. Evaluation

We performed usability tests and collected end-users opinions about our application (both from professors and from students), to see what can be improved or changed in the future in the application.

Methodology: The conducted usability test consisted of an introduction, tasks for modules from application, a short interview and a post-test questionnaire. We instructed the participants to think out loud and express their thoughts during the test. After the task series that we communicated verbally to the participants, we gathered their assessment of the overall experience using the QUIS (The Questionnaire for User Interaction Satisfaction) scale. The tasks that users performed covered the main options from the application and each session took around 4-5 minutes. In some cases, users have executed the steps without having seen them executed in advance by someone, just as there were cases where they performed the tasks after someone else went previously through the steps, presenting them.

4.1 Professors opinion

During all experiments, before showing our application to students, we asked professors to use it. We have recorded their experience with the AR application while they were performing usual tasks.

Participants: We collaborated for evaluation with six participants from the professors involved in the student's classes. Their selection was random, the group being formed of 4 women and 2 men. 5 of them didn't have previous experience with AR applications. They used the AR application during two or three consecutive days.

Results: During the test session we noticed that the professors had the best experience while performing the tasks after someone else. They found quickly the application options and they were able to use them appropriately. The execution of tasks wasn't very fast, thus devices have not been blocked very often. The participants were asked to rate their experience with a mark from 1 to 9, where 1 stands for confusing/frustrating experience, and 9 for clear/pleasant experience. The user responses to the post-test questionnaire show that the "overall look and feel experience" is most appreciated by participants (8.16), followed by "selection controls", "menus", "game options" (all with scores around 8) and by "Status bar", "Tests" and "Collaborative options" (all with scores over 7).

4.2 Students opinion

After our initial interaction with professors we presented our application to their students. Again, we have recorded their experience with the AR application while they were performing the same tasks as professors.

Participants: We collaborated for evaluation with twelve students from the classes involved in the experiments. Their selection was random, the group being formed of 6 girls and 6 boys (from 9 years old to 16 years old, from primary classes to high school classes). All have previous experience with tablet or smartphone games, and only 4 of them didn't have previous experience with AR applications. They received the application and their interactions with AR application were during one day.

Results: From our observation during the test sessions, the students had the best experience while performing the tasks after previously observing someone else doing the tasks. If at the beginning they follow very strictly the steps of the tasks, after the second or third application they performed the tasks with the goal to obtain the fastest results (in order to finish first the tasks). They found quickly the application options and they were able to use them properly. In many cases they press too fast on the screen of the devices and the majority of them managed to block the applications during the experiments. Similar to professor experiments, the students were asked to rate their experience with a score from 1 to 9, where 1 stands for confusing/frustrating experience, and 9 for clear/pleasant experience. Again, the user responses to the post-test questionnaire show that the "overall look and feel experience" is most appreciated by participants (around 8.5) followed by rest of the options which are between 7.5 and 8.

4.3 Remarks

When comparing to professors, students generally didn't follow very strictly the steps of the tasks, and they tried to find shortcuts to finish sooner the assigned tasks. Also, they blocked more often the applications, mainly because they tried to obtain better results in game or in evaluation components. If, at the beginning, students from primary school were impressed by application created for students from middle and high school, after explanations they were very happy to use this application even they didn't obtain very good results. Also, they were very verbose and very happy to solve together tasks.

Recordings analysis clearly showed that:

- The user interfaces based on AR look very attractive and were appreciated positive both by professors and by students;
- Even in the few cases where UI was a bit confusing, after explanations and after given examples, things became more clear;
- The devices present minor performance and stability issues, especially when moved fast or when more than one time the touch screen is fast clicked;
- Social interaction between participants, visual effects, and game dynamics are well received by everyone;
- Both professors and students agree that the lessons can be more attractive with AR application and it can help professors better present the new content of the lessons.
- Also, evaluation based on games reduce the stress of the children and

can provide a fast way to professors to see which the level of an entire class is.

5. Conclusions

Today's technology is in a continuous change, leading to numerous benefits. Aside from the easiness in which the information is delivered, the attention of the educational software users is collected by the new ways of presenting the disciplines. As we mentioned in the previous sections, children are learning more in this manner, then the classic one. In achieving our project, we took into consideration this aspect. In relation to a small part of Geography, using the software assures retention of the general knowledge about European countries.

The application is also intended to develop the memory of the users with the help of Augmented Reality. The fact that the printed maps don't contain details, represents an exercise for the users. They are inclined to search in their memory first and after that to validate what they know or learn new things. Many times we have the impression that we have withhold the information, but during the test we figure that the facts aren't that way. Through the reiteration of the game, the information about every country will be remembered in a better way.

In our opinion, this type of application brings a major benefit in developing the general knowledge. The idea of learning new information throughout the iteration of a game is a good one, because students will acknowledge new information, without them noticing the learning process. They will think that they are playing a game and they have to retain as many details as possible in order for them to become the best player.

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