A Complex Workflow for Development of Interactive and Impressive Educational Content Using Capabilities of Animated Augmented Reality Trends

Ivanka Tsvetkova, Diyana Kinaneva, Georgi Hristov, Jordan Raychev, Plamen Zahariev
Department of Telecommunications
University of Ruse "Angel Kanchev"
Ruse, Bulgaria

itsvetkova@uni-ruse.bg, dkyuchukova@uni-ruse.bg, ghristov@uni-ruse.bg, jraychev@uni-ruse.bg, pzahariev@uni-ruse.bg

***Abstract* — the modern Information and Communication Technologies (ICT) have changed the way we perceive and interact with the surrounding environments. One of the many new ways to receive information in the digital world is trough Augmented Reality (AR) products. This new technology provides the means for real time integration of digital content directly over the visible surrounding objects. In this way, the AR products provide the students with new ways for improvement of their skills and knowledge. Engaging students actively in their own learning process is an important pre-requisite for knowledge building. Using AR in the education process will help the students memorize the contents much easier and they will gain knowledge faster.**

In this paper we present a complex workflow for the development of interactive and impressive educational contents and for the improvement of the students learning perceptions. For the creation of these modern educational learning materials, the animated AR trends are used. Based on the presented workflow, four AR applications are developed and discussed. Another benefit from the proposed workflow is represented by the integration of the augmented reality applications with the existing textbooks or with other learning materials. In this way, there is no need to reprint the old textbooks or to create new ones.

Keywords — Augmented reality, virtual reality, 3D models

I. INTRODUCTION

Many studies on the different learning methods and their impact for knowledge gaining have been made in the past decades. Some of these studies are focused on the traditional educational methods, while others are also investigating the influence made by the introduction of the modern learning technologies. One of these studies is considered as a fundamental one [1], as it introduces the concept for the cone of learning. According to the observations presented in this study, after two weeks the people remember only 10% of what they have read, 20% of what they have heard, 30% of what they have seen, 50% of what they have seen and heard, 70% of what they have said and around 90% of what they have said and did [1]. Based on this, it can easily be concluded, that with the introduction of additional visual and interactive contents, the learning process will become more entertaining and also more memorisable by all students. Many different approaches for integration of additional content or for modifications in the content delivery methods have been previously discussed and analysed. For the purpose of this paper we will focus on the AR trends and the possibility for their involvement in the educational process.

II. AUGMENTED REALITY SYSTEMS AND TRENDS

The ability to overlay computer graphics onto the real world is commonly called Augmented Reality (AR). Unlike immersive Virtual Reality, AR interfaces allow users to see the real world at the same time as virtual imagery attached to real locations and objects. In an AR interface, the user views the world through a handheld or head mounted display that is either see-through or overlays graphics on video of the surrounding environment [2]. AR interfaces enhance the real world experience, unlike other computer interfaces that draw users away from the real world and onto the screen.

Augmented reality can be used to model objects, allowing learners to envision how a given item would look in different settings. Models can be generated rapidly, manipulated and rotated [3]. Students receive immediate visual feedback about their ideas and designs in a way that allows them to spot inconsistencies that need to be addressed. In addition AR could be used for playback of audio and video contents. Animated videos are perfect to explain how a product works or to present concepts and processes in a simple and easy to understand ways [3]. When students use AR with video content, they can study the subjects they have missed or they can replay a specific lecture as many times as they need. The biggest advantage of this is that the students can watch and hear the contents on demand. Moreover, these contents are usually entertaining to watch, which makes their learning quicker and more efficient. This is proved by [3], where a prototype animated AR system was configured for assembly tasks and an experiment was conducted with two groups - one has used this system and the other has not. Another educational function, where AR will be suitable, is in the area of skills training. AR goggles have already been used to train individuals, especially in specific tasks, such as hardware mechanics in the military, or airplane maintenance, at companies such as Boeing [4]. The AR goggles are able to display each step in a repair process, identify the tools needed and include textual instructions.

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When designing an AR system, four aspects must be considered – the combination of the real and the virtual worlds, the real time interaction, the 3D registration and the portability of the solution. In almost all virtual environment systems, the user is not allowed to walk around, mainly due to the hardware limitations. However, some AR applications require the user to explore the surrounding environments, which makes portability an important issue. The main AR Components are:

A. *Scene Generator*

The scene generator is the device or software responsible for rendering the scene. Rendering is not currently one of the major problems in AR, because a few virtual objects need to be drawn, and they often do not necessarily have to be realistically rendered in order to serve the purposes of the application [5].

B. *Tracking System*

The tracking system is one of the most important problems in AR systems. The objects in the real and virtual worlds must be properly aligned with respect to each other, or the illusion that the two worlds coexist will be compromised [6]. The tracking system performs processes that are called recognitions of the real objects or of some markers on it. In this way, any image, object, face, body or space can be recognized and used to superimpose the virtual object. During tracking, real-time localization in space of the image, object face, body or space is performed and finally media in the form of text, video, 2D, 3D, etc. is superimposed over it [7]. In this system, a camera continuously snapshots the targeted object and processes the image to estimate the position, orientation and movement of the visualization display with respect to the target object.

C. *Display*

Most of the Displays devices for AR in the past were Head Mounted Displays, but now mainly smartphones are used. Five major classes of AR systems can be distinguished by their display type – Optical See Through, Virtual Retinal Systems, Video See-Through, Monitor Based AR and Projector Based AR [5]. In this paper we use Monitor Based AR with a smartphone, because our goal is to create products, which can be used from everyone without the need to purchase additional equipment.

III. General Requirements for Development of AR Applications and Their Contents

The process of development of interactive and impressive educational content using the capabilities of the animated augmented reality consist of several stages, which are shown in the Fig. 1.

The contents, which can be inserted in the AR applications, can be 3D models, animated 3D models, videos, pictures, texts or a combination of all of these. The creation of AR applications involves several steps – from preparation of the required materials, through software processing, to the actual use of the AR application. To develop an AR application it is first necessary to specify the image target, which can be any figure from a book, textbook or even a real object. Then, a software is used to perform the image tracking and to superimpose the virtual object on the top of the image target. In the end, the application is exported and installed on a mobile device with a camera. In the next subsection these steps are investigated in greater details.

A. *Creation of the Image targets*

The image target can be any existing object, like a figure in a textbook, a brochure, a poster, lecture notes or other hard copy materials. It is also possible to have the content developers create a completely new image target. Also there is no limitation to use the electronic copy of the physical target. For educational applications, it is appropriate to use textbooks or lecture notes. These objects are needed to present the AR content. There are four types of AR tracking – fiducial marker based tracking, hybrid based tracking, modelled based tracking and natural feature tracking. A model based approach uses prior knowledge of the 3D objects in the environment along with their appearance [8]. Using geometrical representation of the 3D objects, we can manipulate their position and orientation matching them to their counterparts in the field of view. Fiducial marker based tracking is the most often used technique to make AR apps. The markers are used for easier recognition in the field of view and typically have high contrast. They relate to the specific points in space and are used to calculate the distance and the angle, at which the device is orientated. Typical markers used in AR are black and white squares with geometric figures [8].

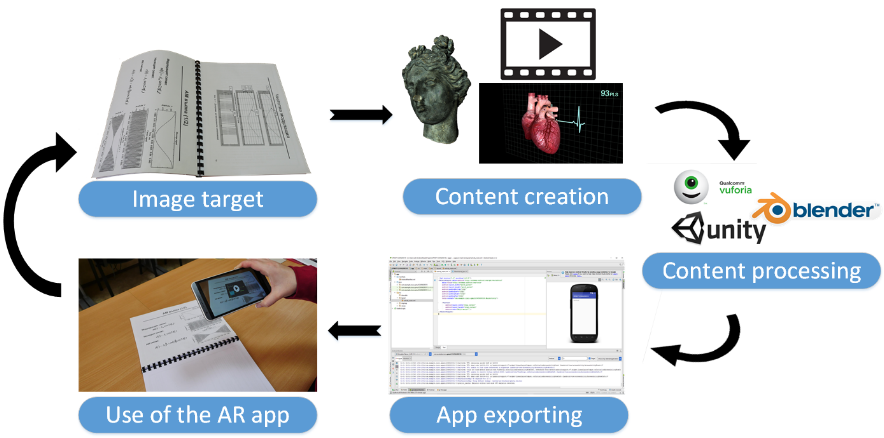
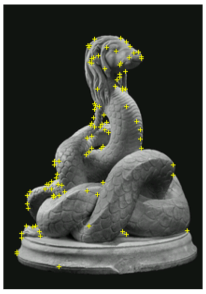


Fig. 1. Workflow for development of interactive educational content

In this paper we use the Vuforia software for creation of AR apps [9]. Unlike the traditional fiducial markers, data matrix codes and QR codes, the Image Targets, which the Vuforia SDK can detect and track, do not need special black and white regions or codes to be recognized. The SDK detects and tracks the features that are naturally found in the image itself by comparing these natural features against a known target resource database. Once the Image Target is detected, the SDK will track the image as long as it is at least partially in the field of view of the device camera [10].

There are two phases in the development of the Image Targets. First, the raw images have to be designed and then they have to be uploaded in the Vuforia Target Manager for processing and evaluation. For example, Fig. 2(a) presents an image from a textbook, which is uploaded to the Vuforia Target Manager and it is evaluated with the highest grade. Fig. 2(b) shows the features, which will be used for the recognition process. If the image is not appropriate to be used as Image Target, there will be fewer yellow crosses or even none at all.

a) Textbook image



b) Evaluation of the image

Fig. 2. Development of an Image target from a textbook image

As Image Targets the developers can use any planar image that provides sufficient detail to be detected by the Vuforia SDK. Vuforia is able to recognize and track targets by analysing the contrast based features of the target that are visible to the camera. To improve the performance of the targets, these features have to be enhanced, through adjustments of the targets design, rendering and scale and how they are printed [10]. For the development of the interactive educational content, we use as targets the pages from existing textbooks.

B. Development of the digital content

Still images, video clips, 3D models or animated 3D models can be used as content of the AR applications. For example, still images can be used for checking the correct answers from the chapter tests of a textbook. Video content is appropriate for short explanations on a specific task or for process guidelines. 3D models can be used to show various organs, like a brain or a heart or to display complex systems. In this way, the students can obtain visual impressions of the objects, they can rotate them or closely analyse them. Animated 3D models can be used to show the movement of animals and vehicles, fluid flows, modulation of signals, etc.

In the following chapters, we will present several AR applications with different contents, including video and 3D models.

While the multimedia digital contents are nowadays relatively easy to create, the development of 3D models is still presenting itself as relatively challenging process for many people. There are two different ways to make 3D models – to create them from scratch using specialized software products or to digitalize real world objects, either by using a photo cameras or 3D scanners. Both of these methods are very specific and require a lot of time and specific knowledge. In this paper, we will not discuss the first method. Instead we will focus on how the real world objects can be digitalized.

The photogrammetry principles can be used to make full colour, highly accurate and realistically textured models of buildings, archaeological sites, landscapes and objects. Close range photogrammetry of historical objects offers the possibility to digitally preserve artefacts before they get lost, damaged or timeworn. Additionally, the method provides means to perform digital measurements, manipulations and other analyses, which present insights into the material and the structure of the objects that might not be visible to the naked eye. Photogrammetry represents a technique for taking multiple overlapping photographs and deriving measurements from them to create 3D models of objects or scenes [11, 12]. The basic principle is quite similar to the way the software of many cameras makes it possible to create panoramic pictures by stitching together overlapping photographs into one 2D mosaic. Photogrammetry takes the concept one step further by using the position of the camera, as it moves through 3D space, to estimate X, Y and Z coordinates for each pixel of the original image and create a detailed database about them. When the photo-shooting of the object is finalized, specialized software is used to process the images. The first step of this process is to align all photos (Fig. 3). This is done by comparing the pixels in the photos and finding matching sets, which are used to estimate the camera position and the 3D geometry of the object. The second step is the creation of the dense cloud [13]. Once satisfied with the alignment, the sparse point cloud, a mere fraction of the total data, is processed into a dense cloud, in which each matching pixel is placed, based on its X, Y and Z coordinates in 3D space. The next step is to build a mesh by connecting each set of three adjacent points into triangular shapes, which are combined seamlessly to produce continuous mesh over the surface of the model. The final step is to build and apply the texture (Fig. 4). For this purpose, the original images are combined into a texture map and are wrapped around the mesh. This leads to a photorealistic model of the original object.

The 3D reconstruction of large objects differs mainly in the digitalization process, where based on the size and the location of the object the ground camera images might not suffice and drones can be used to capture additional aerial pictures of the object or the surrounding area. In order to speed up this process and to use the drones more effectively, specialized software for flight planning can be used. This software generates the mission plan, which is performed autonomously by the aircraft, but only after the user inputs the necessary flight setting [14]. The reminder of the reconstruction process remains the same – the images are processed and the digitalized model can be exported in different formats for visualization.

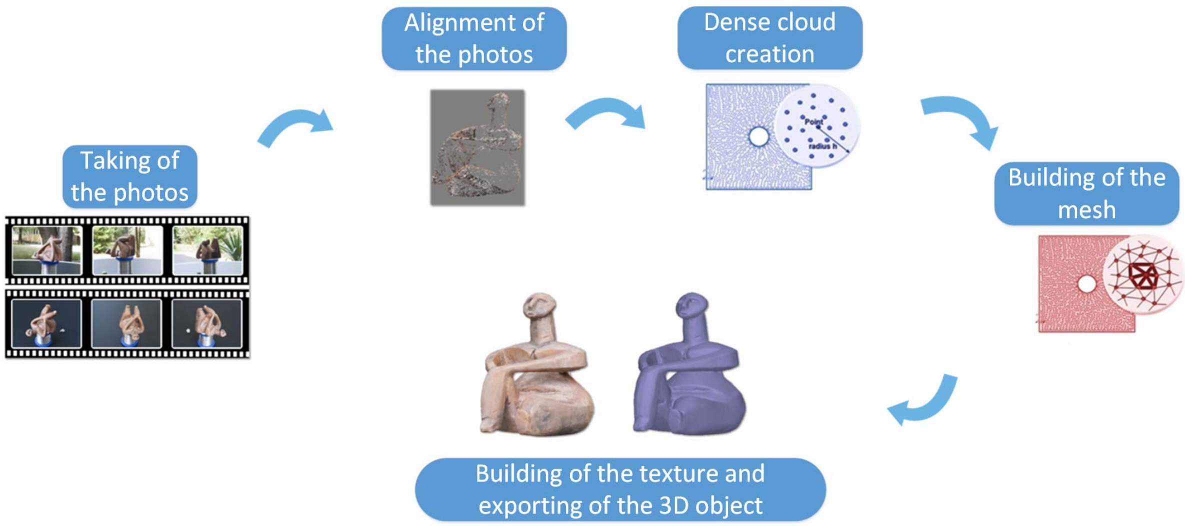


Fig. 3. Processing of the digitalized data and creation of the 3D model

A more simplified method for object digitalization is to use specialized 3D scanners. There are several 3D scanning technologies, mainly involving devices with laser or light sources, which estimate the distance to the object. The 3D scanning process is shown on Fig. 5.

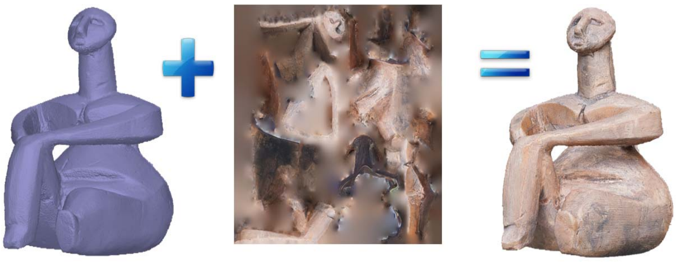


Fig. 4. Building and applying the texture on the model

The purpose of the 3D scanner is usually to create a point cloud of geometric samples from the surface of the object. These points can then be used to extrapolate the shape of the subject (a process called reconstruction) [14]. If colour information is collected at each point, then the colours on the surface of the subject can also be determined. The picture produced by the 3D scanner describes the distance to the surface at each point in the picture. This allows the three dimensional position of each point in the picture to be identified [14]. For most situations, a single scan will not produce a complete model of the object. Multiple scans, from many different directions are usually required to obtain information about all sides of the object. These scans have to be brought in a common reference system, a process that is usually called alignment or registration, and then merged to create the complete model.

C. *Software processing of the digital content*

After its creation, the 3D model should be processed. There are many software products, which can do this. Two authoring paradigms have been used to create AR solutions – stand-alone and AR plug-in approaches [15]. Stand-alone augmented reality authoring tools are software products with all the necessary components for the development of complete AR experiences. AR plug-ins are third-party software components installed on host applications in order to enable additional features. Augmented Reality SDKs facilitates many components within the AR application – AR recognition, AR tracking and AR content rendering [7]. The recognition component works as the brain of the AR app, the tracking component can be defined as the eyes of the AR software, while the content rendering is simply the reproduction of the virtual objects over the real scenery [7]. Many different tools are provided to developers through SDKs, which are used for the development of the recognition, tracking and rendering parts of the AR application.

For the purposes of this paper we have used two software products – the game development engine Unity [16] and the software platform for creation of AR applications Vuforia [9].

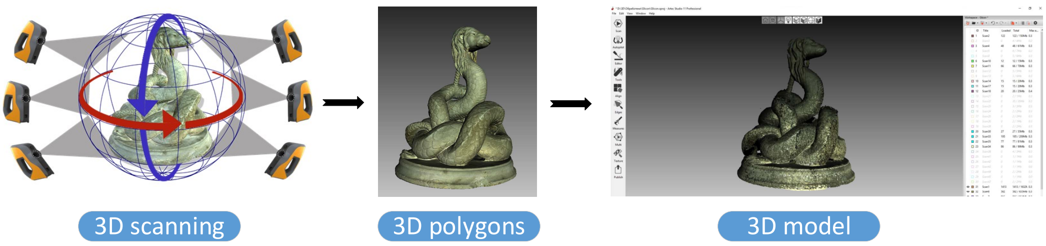


Fig. 5. Workflow of 3D scanning to create a 3D model

Vuforia is a SDK, which allows the developers to easily add advanced computer vision functionality to any application, allowing it to recognize images and objects and interact with them in the real world. This product consists of different components, like Target Management System, available on the developer portal (Target Manager), Cloud Target Database and Device Target Database and the Vuforia engine itself [10]. A developer simply uploads the input image for the target that he wants to track. The target resources are then accessed by the mobile app either through cloud link or directly from the mobile device local storage. The Vuforia platform supports AR application development for Android and iOS devices. Vuforia Model Targets enable physical objects to be recognized and tracked using a digital 3D model of the object. Model Targets support the recognition and tracking of objects by their shapes. Objects are recognized by the Vuforia SDK using a specially prepared database that is generated by processing a digital 3D representation of the object using the Model Target Generator application [10]. CAD models are recommended for this purpose, as they capture the geometry of the objects with a high degree of precision. If the digital content is a video clip, it can be loaded locally or from a URL. In order to create the AR app using Vuforia, the developer first needs to add it to the Unity development environment. One of the key areas of this development software is the Hierarchy Window, which is tied to the Scene View. When the GameObject in the Hierarchy Window is clicked, it becomes active in the Scene View, as shown in Fig. 6. This object can then be modelled as 3D target.

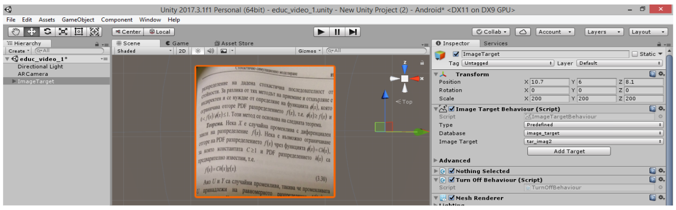


Fig. 6. Main view in Unity

The Hierarchy Window lists all the objects in the developed application (like videos, 3D models, music files, effects, etc.) in alphabetical order. The developers can also group certain objects together, by creating a hierarchical arrangement and assigning Parent and Child categories.

D. *Exporting of the AR application*

After the project is created, it needs to be exported for use with a mobile device. With the method discussed above, the developer can export the app for both Android and iOS devices. An example of the AR application exporting process, for use on an Android devices, is shown in Fig. 7

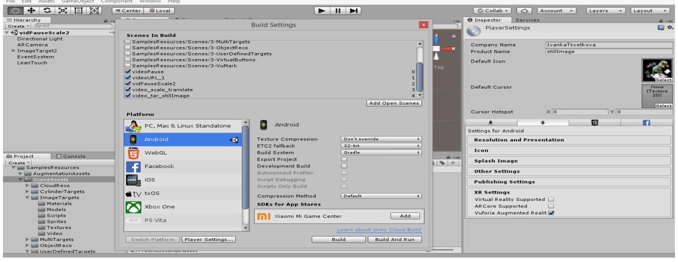


Fig. 7. Exporting of the AR application for use on an Android mobile device

E. *Use of the AR application*

The AR application needs to be installed on a mobile device with a camera. When the app is started and an image target is placed in the field of view of the camera, the AR content is displayed. When the AR application or browser plug-in, used on the device, receives the digital information from the known target, it begins to execute the programing code and displays the specialized content – 2D image, 3D model, video clip, etc.

IV. Development of Interactive and Impressive Educational Content for Use in AR Applications

Depending on the type of the planned augmented reality content and the devices available for the students to utilize the AR application, many tools are now available for educators wishing to create augmented reality products for learning purposes. We have developed several AR test applications, where for the digital content we have used 2D images, video clips, 3D models and animated 3D models. The development of the AR applications was done using Unity and Vuforia, while the apps were exported for use on any Android or iOS device. The first example application shows how the students can check the answers of their tests in the end of the textbook chapters (Fig. 8). The advantage of this method is that they don't need to search back in the textbook for every answer and they cannot also get tempted to look in the answer pages. Instead, the students can use their own smartphones to see the correct answers, whenever they are done with the tests.

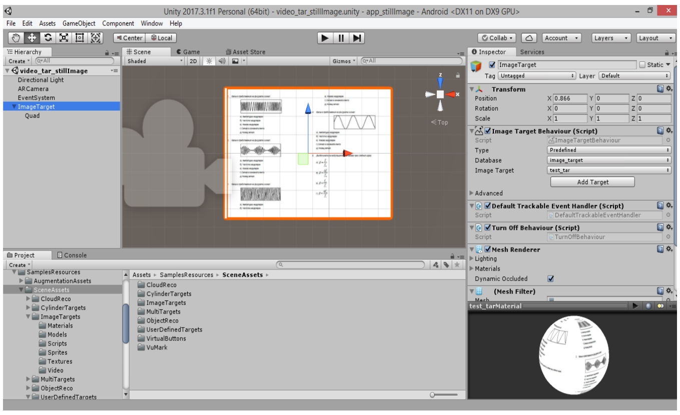


Fig. 8. Development of the AR application for tests verification

In the Radio communication systems course at the University of Ruse (Bulgaria), students are given both a hardcopy of the textbook and a smartphone application, which they can use to visualize additional AR content, like video clips. The process of creation, of an AR application for playback of video content, consists of four steps. The first one is to create the Image Target. In our case we have used images of the textbook pages. Then the digital content is created, which in our case represents existing video clips. Both the target images of the corresponding pages and the video clips are then loaded in the database for the application in Vuforia. The third step is the processing of the content, but before that some general setting have to be set, like the activation of the database, the arrangement of the hierarchical components view, etc. All scenes should be prepared, like shown in Fig. 9. The process starts by adding a new AR camera to the working area.

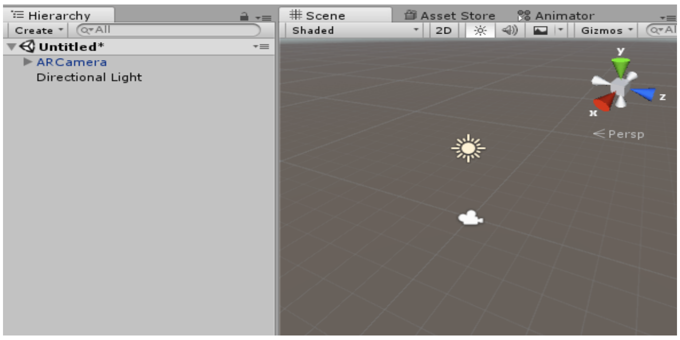


Fig. 9. Scene preparation

After the introduction of the AR Camera, its properties should be carefully configured. The process continues with the loading of the Image Target on the scene (Fig. 10).

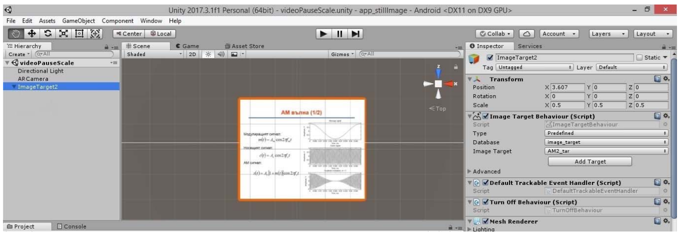


Fig. 10. Image target in Unity

The last step in the process is the addition of the AR content, which in this case is a video clip. Additional settings for scaling, pausing and playing of the video clip can also be implemented. Following this, the AR application can be exported and installed on any mobile device. The result is a simple, but effective application, which impresses the students and makes them learn the course materials, while enjoying this new technology in their hands (Fig. 11).

Fig. 11. Starting of a video clip using the specialized AR application

The use of video clips as AR content represents only the tip of the iceberg for this technology. The integration of detailed 3D models can lead to the development of far more interesting and exciting applications. A huge potential application area for this technology is in the history classes, where 3D models of existing artefacts can be visualized and presented on top of the old fashion textbooks. Unlike the conventional learning methods where the students use textbooks, on-line materials or video lectures to observe pictures, read text or watch videos, the AR applications give the possibility to see the 3D models, to rotate and zoom them and to closely study every detail from different perspectives. The actual objects of the study can be in museums or in remote locations, which will make them impossible to see in the real world, but even so the students will be able to reach and learn about them through their 3D models. The creation of a 3D model of a real world object is now much easier with the widespread of easy to use 3D scanners. Multiple scans, from many different directions, are used to obtain information about all sides of the object. These scans are then processed in specialized software products and aligned together to form the digital model of the object (Fig. 12).

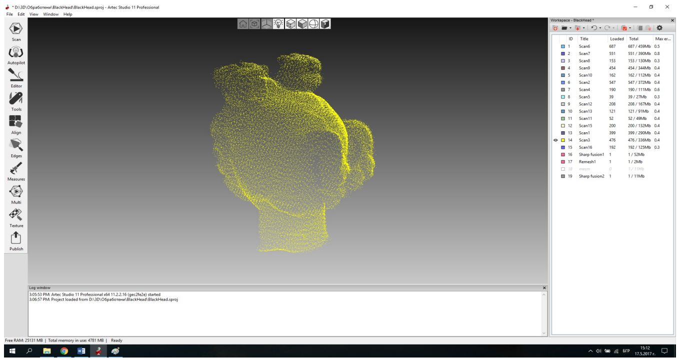


Fig. 12. Software processing of the photos for creation of the model

Once the 3D model is created, it can be imported in the Vuforia environment for use in the AR application (Fig. 13). The development process of this kind of applications, follows the same steps like in the previous two examples.

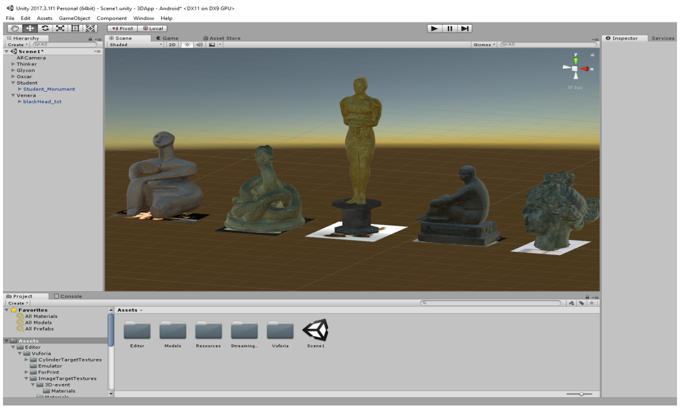


Fig. 13. Software processing of the content for the AR application

Once the application is created and exported it can be used on any mobile device to enhance the perceptions about the studied objects by visualizing their 3D models (Fig. 14).

Fig. 14. The AR application and the visualised 3D model

To further improve the AR applications, the 3D models can be animated and various sound effects can be added. This will significantly enhance the learning process. However, the main steps for the development of the applications remain the same. In this way, we have created another application, which displays the movement of a mammoth within a grassy terrain.

During the development of the discussed applications, we have noticed some minor disadvantages in the process and the technology itself. Lighting and focus related problems limit the performance of the AR applications. The mobile devices used to provide the digital content are characterized by their fairly limited processing power and their restricted storage capabilities. Based on this, the applications should not be very large and should use minimum processing power. The creation of the 3D models is time-consuming and requires deep knowledge and practical experience with many different software products, which may not be easy for every content creator, like the teachers and the lecturers.

The disadvantages, we have acknowledged, can be divided in two groups:

- Physical limitations: the digital content may not be loaded if the paper, used for the target image is glossy, if an inappropriate image target is used or if the light in the room is not enough, etc.

- Software limitations: if a 3D model is used in the AR application, it should be made out of as few polygons as possible, because the mobile devices will struggle to visualise it. If a video clip is used, it should not be too large or long, because the mobile device will run out of resources and the application will lag or stop.

V. Conclusion

In this paper we have presented a workflow for development of interactive and impressive educational contents using the capabilities of the animated augmented reality software products. Students can use different AR solutions to improve their skills or to gain knowledge faster. The AR products give the students new possibilities to observe animated three dimensional models, video clips or 2D images, thus significantly enhancing their learning process. The additional content can be created and then applied on a particular page of the existing textbook and when the students reach that page a 2D image or a 3D model can be loaded and displayed on their mobile devices.

Augmented reality applications are written using special programing engines, which allow the developers to bind animations or contextual information to an augmented reality target in the real world. In the paper we have presented several AR applications, which are used in different areas and provide different digital contents to their users. Whatever the content is, the development steps are pretty much the same.

The AR technologies have huge potential in the educational sector and can be considered as the next evolutionary step for the creation of modern digital learning content. In the paper we have also presented some minor issues and disadvantages from the use of this technological solutions, but with the constant improvement of the technical capabilities of the mobile devices and with the improvement of the SDKs for development of AR applications, these issues will be solved and we will see much larger number of AR applications for educational purposes.

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