EXPLORING DACIAN CULTURAL HERITAGE WITH dARcit AUGMENTED REALITY APPLICATION

Abstract: This paper is focused on highlighting the advantages of using modern augmented reality applications to support the widespread dissemination of Cultural Heritage assets. This kind of applications have the potential to improve the user experience when they are visualizing a hard cover printed book or catalogue. The main advantage of this solution is to allow users to use their personal smartphones and tablets to access additional interactive content related to main subject of tangible books. Using the proposed solution described within the article any printed material can become interactive using multimedia elements such as: audio files, 3D models, images, videos (2D, 3D, 360°), 3D text or any other form of digital content. The application adds multimedia information on top of the printed information increasing the degree of understanding of the information presented in the form of a book / catalogue, regardless of the time in which it was written and published.

Keywords: *augmented reality, digital content, cultural heritage, mobile application, customisation.*

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1. INTRODUCTION

It is important to state the fact that the devices that are capable to generate augmented reality experiences are continuing to evolve and change at a rapid pace. Alan B. Craig[1] has presented this evolution within his „*Understanding Augmented Reality*" book and highlights that the underlying principles necessary to create useful and exciting augmented reality applications are timeless.

Early augmented reality applications have been developed since the late 80s – early 90s in various academic areas. During the following years there was an exponential growth of digital applications that was mostly sustained by the wide spread adoptions of personal computer along with Internet access. Steve Mann[2], known to be one of the early pioneers that developed wearable computing devices suited for augmented reality applications; he proposed a head-mounted display (HMD) fitted with video cameras that were capable to overlay virtual elements on top of the real word back in 1994. Mann has been involved in augmented reality ever since and he has stated in 2015 that „Augmented reality will only find success if we can make the experience natural for users".

Augmented reality can enhance real-world experiences with the use of various sensory elements. The most used augmented reality enhanced

[1] CRAIG 2013.
[2] MANN 1994.

systems are closely linked to the vision capabilities of the user, others are connected to other elements such as hear or smell.

At the moment augmented reality further development is closely linked with the rapid development of the smartphone industry. The advanced processing capabilities of modern CPU and GPU of mobile devices can enable detailed 3D interactive content in real time on the user's personal devices. The smartphone industry has also equipped their devices with modern fifth generation wireless connectivity (5G) to enable large applications to be downloaded fast, initially these high-speed wireless connections will be available within urban areas across the world[3].

According to the research presented in Tu[4], smartphones are currently recognized as the most common and popular electronic device and large brands are constantly innovating and promoting their new products, which has led to a rising trend in smartphone sales and their worldwide mass adoptions by the general public.

It is important to state that in its current state, augmented reality is a technology that requires smartphones to thrive and to enable a large number of users to interact with digital applications, even if there are dedicated AR devices such as glasses, they are not mass-produced and they don't offer the same advances hardware specifications as smartphones (low light cameras, processing capability, digital storage, connectivity, etc.). On the other hand, modern smartphones have become accessible and much more powerful with each iteration, therefore smartphones are currently representing the hardware devices that can be used to enrich our reality with many computer-generated layers with various information within various augmented reality applications.

As presented in Civantos[5], cultural heritage institutions (galleries, museums and libraries) use digital content to present cultural heritage assets to their audience and to enable them to immerse themselves to a digital cultural heritage environment.

Within his research article Boboc[6] presents that augmented reality has tremendous potential for the promotion and preservation of cultural heritage due to the fact that people are starting to be receptive and that they want social and collaborative experiences that combine two key elements: learning and having fun.

There are studies done by Serravalle[7] that can help us to better understand the dynamics involved in the wide adoption of AR technologies in cultural heritage institutions. Their research is mostly focused on the interactions between all the stakeholders involved in order to obtain different forms of values.

2. AIM OF THE RESEARCH

The purpose of this article is to contribute to the improvement of the overall reading experience of a classic printed material by adding interactive elements enabled using marker-less technologies defined based on the already printed material using augmented reality. Digital electronic books have multiple features compared to classic printed books, they allow the user to quickly search for content, create bookmarks elements, read along audio, dictionary and generally offer "increased usability" compared to a classic book, but without giving the same "tangible" feeling of a printed book.

Based on the facts presented within the introduction of this article, the authors of this paper have decided to create the dARcit augmented reality application to allow users to immerse themselves into interactive digital cultural assets regarding the Dacian civilization from Orăștie Mountains using their own personal smartphones and tablets and the hard copy printed catalogue or its online version[8]. Even if the printed catalogue and its online version have been published in 2016, using the AR application, users can have access to more recent information regarding the elements that are presented within the catalogue, elements discovered or developed after the printing of the catalogue.

The proposed solution comes as a complement to the existing and valuable printed materials that can be improved without the need to reprint them (which in some cases is impossible - the value of the book would be greatly diminished) using multimedia materials and augmented reality technology. Practically over the page of a book or catalogue it is superimposed a virtual environment that can contain various types of multimedia materials that complement the content referred to the respective page and which should lead to a better understanding of the text in question by the reader.

Lately, e-books contain hyperlink elements and digital materials in various forms that increase the interactivity of the content (self-tests, 3D models, video files, audio, simulations, etc.) have started to become popular. This paper presents the underlying principles of an augmented reality software solution which adds useful and exciting interactive multimedia materials to complement the printed catalogue dedicated to the Dacian heritage in Orăștie Mountains. The research presented in this paper aims to identify the limitations and advantages offered by augmented reality technology in order to extend it to valuable books, offering a new type of readers' experience.

3. DESCRIPTION OF THE DARCIT APPLICATION

The augmented reality application has been developed within Unity[9] software and it makes use of Vuforia[10] Engine SDK to define and manage a wide variety of digital markers to enable interactive digital content. The authors of this paper have created a wide variety of digital applications that make use of virtual reality devices[11], haptic equipment[12] and augmented reality applications[13] to promote cultural heritage assets.

The application development followed the gradual introduction of multimedia elements according to their

[3] ZIKRIA et al. 2018.
[4] TU *et alii* 2018.
[5] CIVANTOS 2016.
[6] BOBOC *et alii* 2019.
[7] SERRAVALLE et al. 2019.
[8] NEAMȚU et al. 2016.
[9] UNITY 2019.
[10] VUFORIA 2019.
[11] NEAMȚU *et alii* 2012.
[12] COMES 2016.
[13] COMES *et alii* 2014.

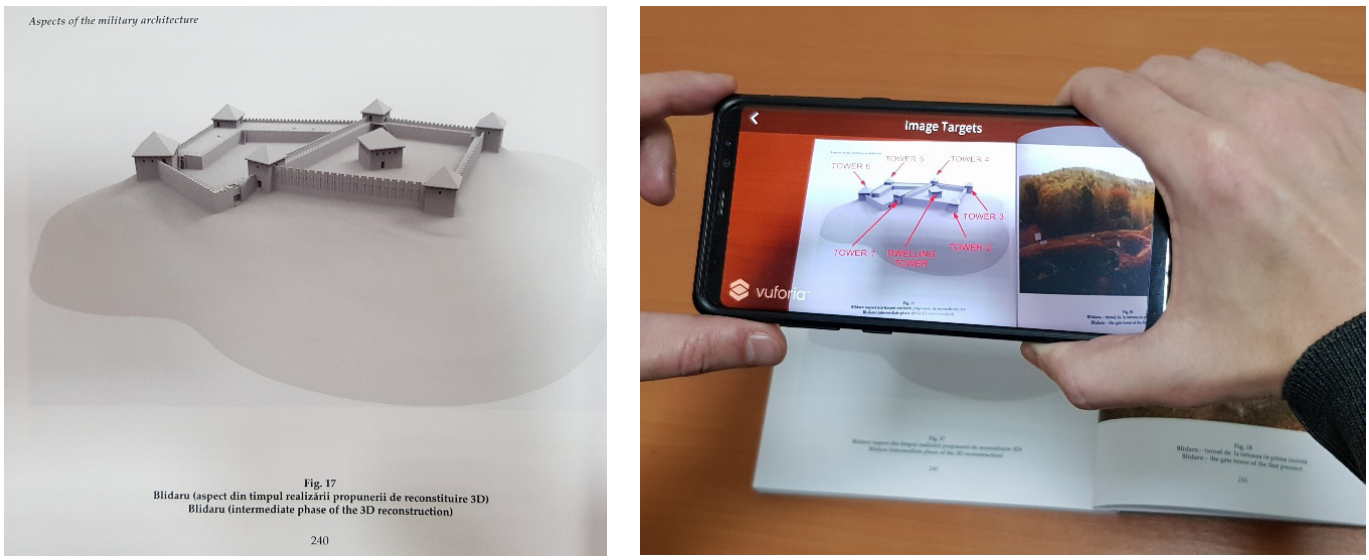

Fig. 1. Left (target picture from the printed catalogue – page 240); Right (dARcit AR environment with text and arrows annotation)

complexity starting from simple text and hyperlinks up to interactive 3D models with animations.

One of the situations in which augmented reality technologies can be used is to provide better explanation regarding a photograph. In Fig.1 is presented a situation where augmented reality technologies can provide additional information to an already existing printed image within a catalogue. The annotations are added automatically using the mobile device, either a smartphone or a tablet (the device`s camera is used to trigger the digital content on top of the video stream provided by the device camera within the mobile device display). The annotations identify certain elements of the photographic composition. From the point of view of the application a marker (digital image) is used from which the text and annotations are attached so that regardless of the position of the camera of the device on which the dARcit application runs, it will correctly indicate the component elements of the photograph by positioning the annotations in the correct area. Text annotations represents the simplest form of interactivity through AR and it can be very useful when multiple components of a monument must be explained. The text annotations can be added as 2D elements such as simple text and arrows or as 3D elements. In some cases, 3D text and 3D arrows can better indicate the desired location.

The next digital element in complexity after texts and arrows are represented by digital buttons with links to various online materials. Using this capability, a text or an image can be annotated and enriched using electronic resources that appear after the initial material is printed. In the dARcit application hyperlinks are used as links to the database containing interactive 3D models of the objects presented in the printed catalogue. Apart from the cases, hyperlink buttons are also used as a link for video files hosted on a social media platform such as Facebook or YouTube. These hyperlinks can also use logo files that indicate the platform where the user will be redirected. The hyperlinks can be directed to a Wikipedia web pages or any other type of material that can be hosted on a webpage (such as photos, GIS data, timetables, etc.). As an example of a hyperlink button, Fig.2 shows the target picture of the online database that is available in the printed catalogue. The

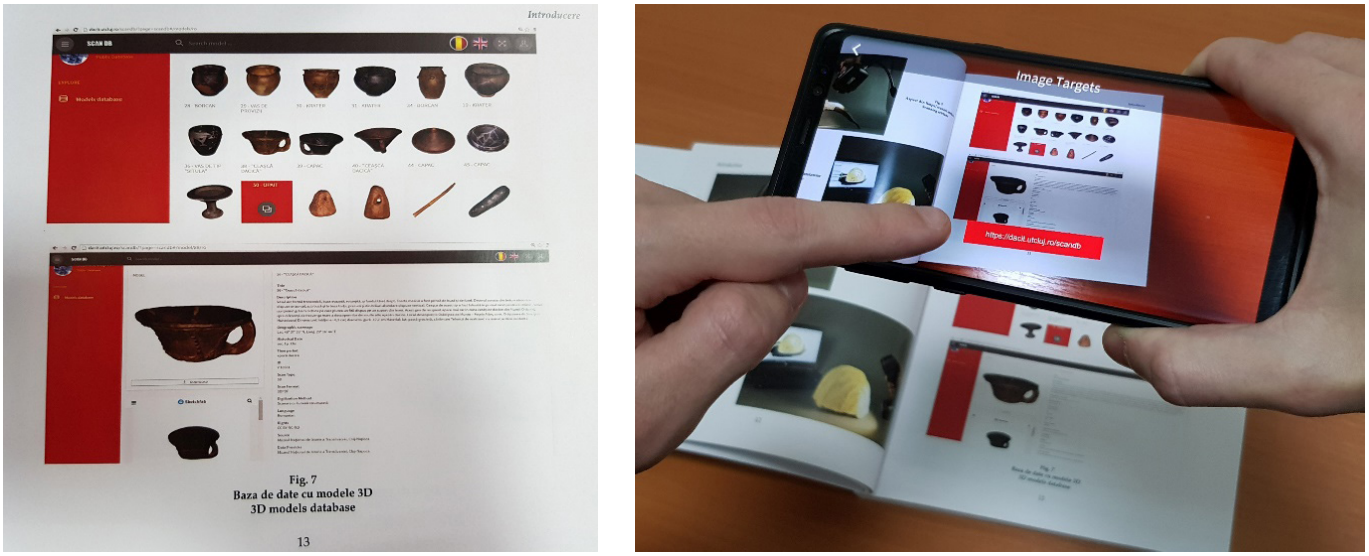

Fig. 2. Left (target picture from the printed catalogue – page 13); Right (dARcit AR environment with hyperlink button to the 3D scanned database)

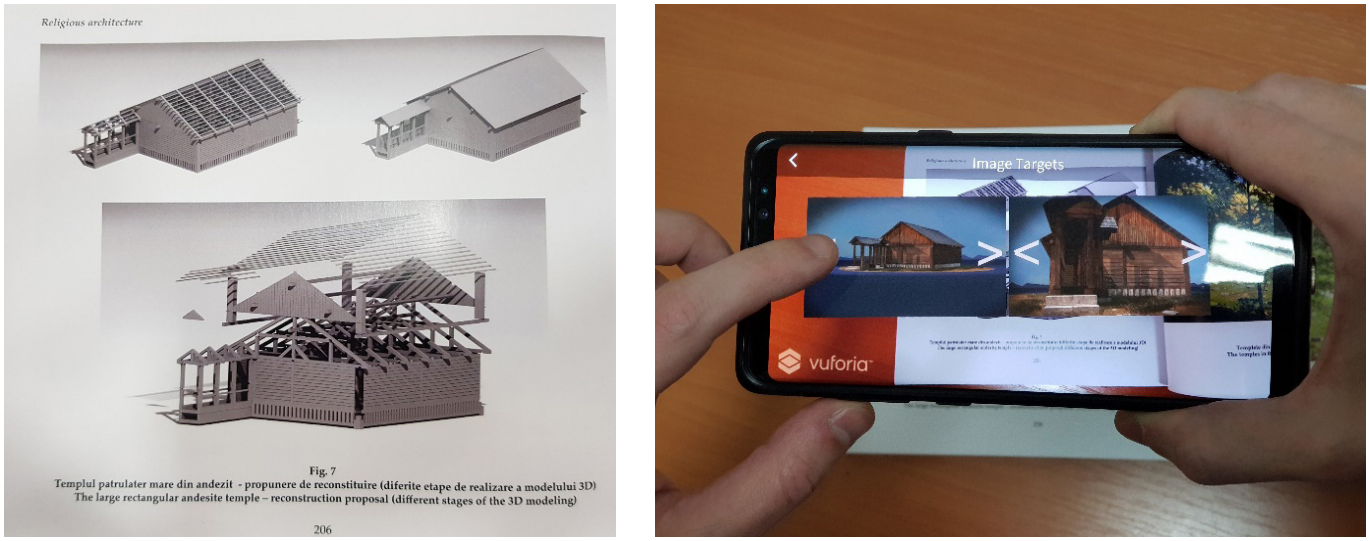

Fig. 3. Left (target picture from the printed catalogue – page 206); Right (dARcit photo gallery that has multiple 3D rendering images of the large rectangular andesite temple reconstruction proposal)

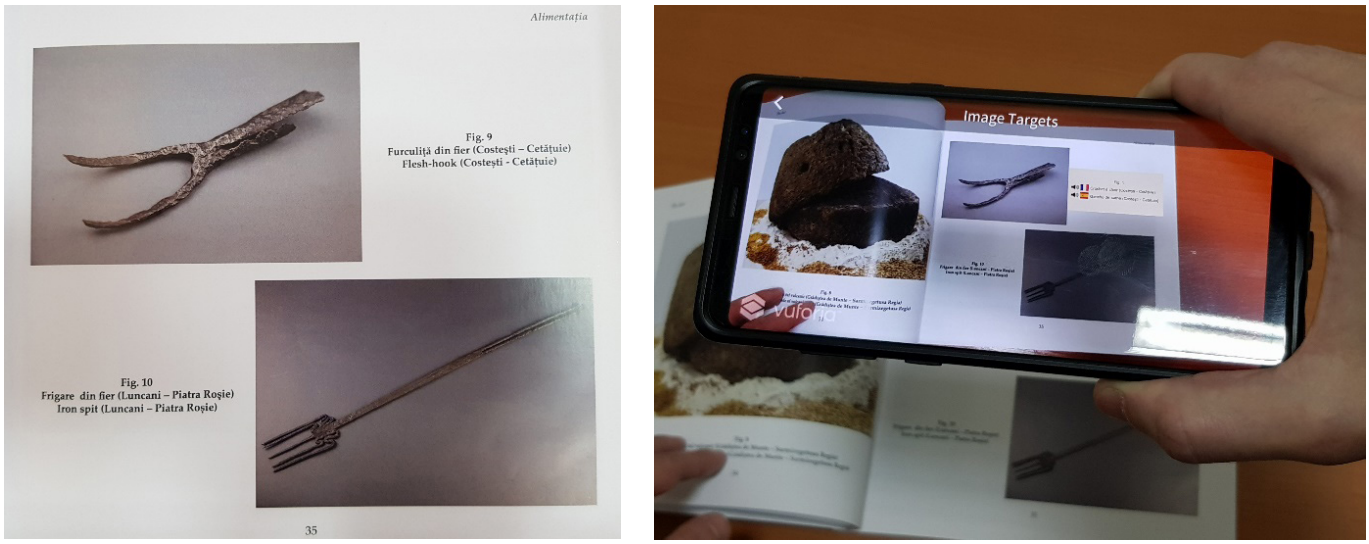

Fig. 4. Left (target picture from the printed catalogue – page 35); Right (dARcit auto translate with audio files support)

hyperlink will take the users to the Dacit[14] online database that currently hosts over 560 3D scanned artefacts of the Dacian civilization from Orăștiei Mountains, the objects are part of the two museums that were involved in the large scale digitization project regarding Dacian cultural heritage assets.

Another element that can contribute to a more enjoyable experience of the reader is the photo galleries that refer to a topic. Usually the printed materials present a limited number of photographs on a single subject, using augmented reality technologies multiple photos can be added in the form of digital galleries that contain a virtually unlimited number of photographs. Moreover, using the application updates, photographs taken after the printing of the catalogue can also be presented, so that the contents of the book can be updated without having the need to reprint the initial catalogue.

Audio files represent valuable assets that bring extra information to a book page, these type of files can be used in multiple purposes such as: adding explanations about a certain image or a portion of the text combined with the text display function can simulate instant text translation into a language other than the one in which it was written. The text to speech function combined with the translation can also be animated and highlighted within the augmented reality application in real time, adding an interesting effect for the end user.

The addition of video materials to a classic text can indulge the reader to an "improved reading experience", in the case studies from dARcit application video files are used as additional elements for the presentation of an archaeological site through aerial video files, to present the construction of some architectural elements (3d animation with exploded-view elements) or 360° video files that allow the user to manipulate the viewing point of view using his smart phone orientation.

Probably the most interactive element that can be used to increase the degree of understanding of a classic material is the 3D model. The 3D models can be representations of an object / monument referred to in the text or it can be a 3D reconstruction of the respective object / monument. For

[14] DACIT 2016.

Fig. 5. Left (target picture from the printed catalogue– page 213); Right (dARcit 3D animation with exploded-view elements of the large round temple digital reconstruction)

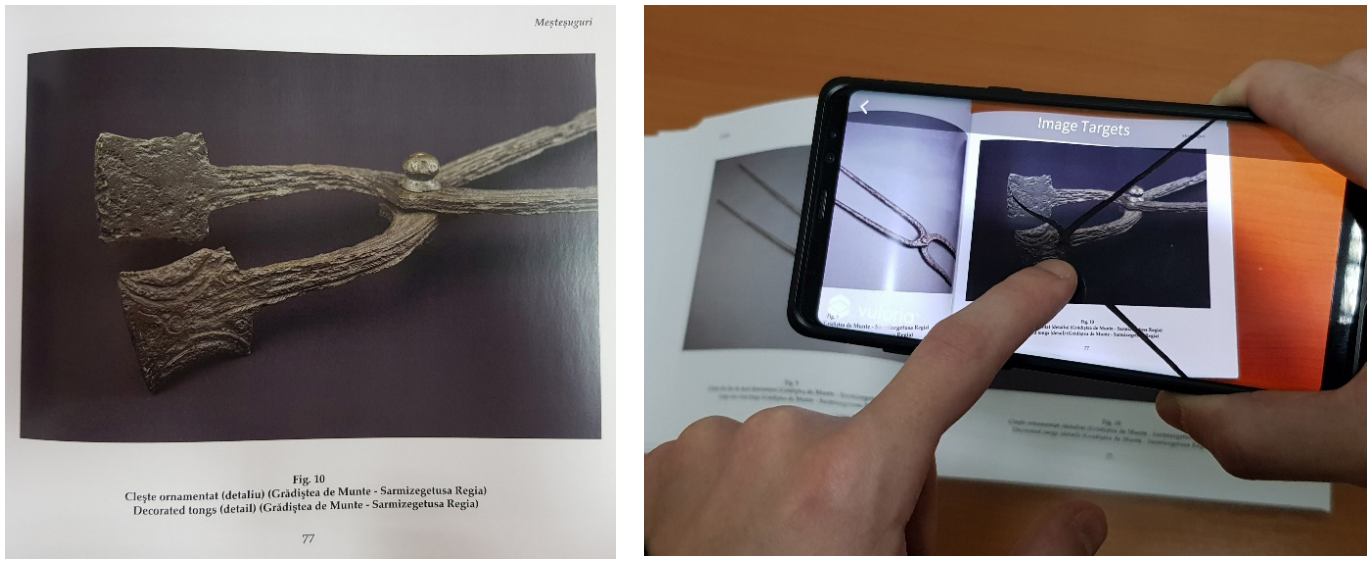

Fig. 6. Left (target picture from the printed catalogue– page 77); Right (dARcit 3D model visualization of detailed 3D scanned decorated tongs)

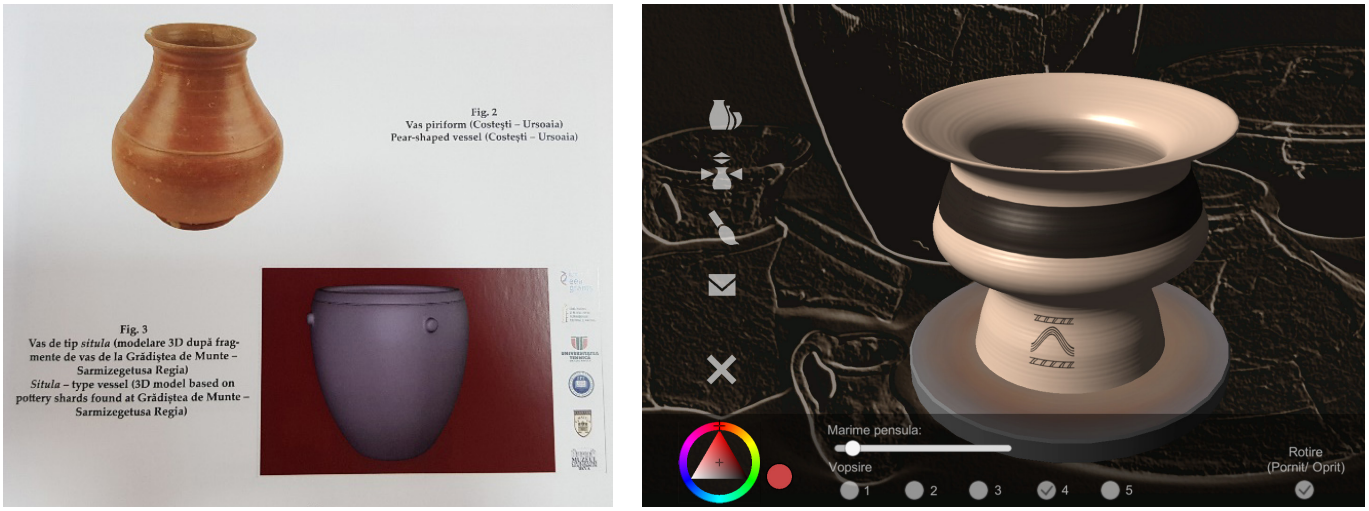

Fig. 7. Left (target picture from the printed catalogue– page 29); Right (touch screen interactive application from the dARcit application that can be used to profile and decorate vessel created on turning wheels)

3D objects, markers can be created to allow the 3D model to be fixed on the printed page so that the user can move the printed page to examine the 3D model from various angles.

The most complex elements that can be added to an augmented reality application are individual stand-alone application that can be triggered by the user within the main augmented reality application. As an example, for this catalogue one of the smaller applications within the AR application is an interactive touch screen application that allows users to create pottery items by manipulating 3D predefined pottery shapes positioned on a rotating wheel. The application also allows users to texture the pottery items with various Dacian artistic patterns and ornaments.

4. RESULTS

The main objective of the DACIT project was to promote the Dacian civilization from Orăștiei Mountains, and one of the dissemination assets developed within this project was the printed catalogue "Dacian Quests in virtual space"[15] that has been printed in 2016. The project created a database with over 560 3D scanned objects, to which other digitized artefacts are added annually. In order to improve the experience of those who read the catalogue, the dARcit augmented reality application was developed, which presents a series of multimedia elements that cannot be presented within the already existing printed catalogue. Thus, a series of video sequences including the 3D reconstruction of Sarmizegetusa Regia sacred area with all the known temples, the architecture detailed components of the large circular temple, and others were included digitally. Along these video sequences, multiple 3D models of reconstructed ceramic vessels and 3D reconstruction of monuments were added as interactive 3D models allowing users to scale and rotate them. These were all linked to various pages of the catalogue, emerging in parallel with the regular reading a new multimedia experience that brings improvements through the prism of new information that can be further added to the printed material using augmented reality technologies.

The application was created in Unity and uses as tracking markers pages from the catalogue, processed with the help of Vuforia Engine. This combination allows the application to run on smartphones, tablets or even on augmented reality glasses powered by Android or iOS.

The application has been tested with both printed and electronic version of the catalogue, the differences in operation being insignificant. The reader can use the digital catalogue available online and use it to trigger the various augmented reality elements of the application. The main advantages of having the printed version of the catalogue when using the application is that the overall experience is better, having to point the smartphone camera to a book, rather to a digital screen, increases the level of manipulation of different 3D objects through the application.

The images that were used as digital markers from the catalogue are images that are rich in detail with good contrast and with no repetitive patterns, this was important since the applications tracks natural features obtained by the augmented reality devices camera.

[15] NEAMȚU/FLOREA/GHEORGHIU/BODÓ 2016.

5. CONCLUSIONS

Using multimedia and AR elements a storytelling scenario can be created parallel to what is described in the printed material, the two stories may be complementary or different. The AR application added multimedia content to an already existing printed text and image layout. The overall presentation of the Sarmizegetusa Regia site was completed with an aerial video (from a drone) that was made after the printed publication, thus opening the premises for making timeless connections that can take the content to another level. The 3D models are automatically positioned, but after their appearance on the screen of the device, the users can rotate and scale the models for a complete inspection. The application was tested indoor and outdoor and the digital markers have rankings between 1 and 5 stars (within Vuforia target manager). Even the one with lower tracking ranking (1 and 2 stars) are usable on the printed catalogue or its online version, the only drawback with the printed catalogue is the glossiness of the paper. The printed catalogue glossiness can be observed in the figures within the article.

The use of hyperlink resources for video files helped to keep the overall size of the application small, the drawback of this is that the application requires the device to be connected to the internet in order to access video files. The alternative would be to include multimedia files directly in the application with the direct consequence that the size of the installed application is directly proportional to the amount of video files and their compression ratios. Having the video files externally linked using hyperlinks ensure the fact that user can access 1080p video files or even larger 2160p (4K videos) acquired by the drone that took multiple aerial videos.

As further developments, the application will include multi-page multimedia elements organized in several scenarios that will allow a user to selectively read for quick extraction of information related to a topic. For example, if a user wishes to document about Dacian pottery then he will be selectively guided to the pages containing the necessary information, both in the chapter for ceramics and in the one for crafts or tools.

The proposed augmented reality application can also be used to improve older books which present historical value can be improved by adding new information related to historical research and discoveries subsequent to the publication of the original text.

A possible use of this kind of application can be in libraries where it can be used in combination with book covers to quickly provide a summary to potential buyers or readers.

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