INSIDDE AR Application: Bringing Art Closer to Citizens by Promoting the Use of Smartphones and Tablets

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***Abstract*—This paper describes the design, development and testing of an augmented reality application for smartphones and tablets that has the main objective of bringing art closer to citizens. The application makes use of an automated recognition and tracking system to identify the paintings being aimed at with the camera and overlaps digital images obtained by means of different technologies (infrared, THz, ultraviolet, X-rays, etc.) in order to unveil some details hidden beneath the outer layers of the painting. The overlapping fits perfectly on top of the original painting thanks to the registration process and it helps to go deeper into the knowledge of the artwork. Once the painting is recognised, the user can access information related to the author, chronology and history as well as additional insights provided by art experts and not commonly included in the guides, contributing to making art more appealing. Furthermore, the developed application includes also audio guides to facilitate the access to art for users with visual impairments, concentrating a great amount of different functionalities into one single device.**

***Index Terms*—Augmented reality application, paintings, recognition and tracking, THz and X-ray images.**

I. Introduction

Museums have been coming out with different and really creative ideas during the last years as a means of increasing the attendance of people and, therefore, approach art to a wider audience. One of the main reasons for the, in occasions, reduced percentage of people that go to museums is the difficulty in understanding the artworks. In order to overcome these difficulties, museums are struggling for making things easier and more appealing for visitants so as to wake up their interest in different branches of art. In the era of new technologies, developing explicative and attractive applications is positioning as a matter of paramount importance for the future of museums but, with the huge amount of different devices, it can be quite cumbersome to pick one out for which to develop these applications.

Desktop personal computers (PC), portable PCs, personal digital assistants (PDAs) or mobile phones are some examples of the extensive list of electronic devices present nowadays in our society. However, the relatively recent appearance of smartphones and tablets has represented a remarkable breakthrough, completely changing the tendency in this field. Smartphones went from representing almost a 54 % of the total worldwide mobile phone sales during 2013 [1], [2] to 66% in the third quarter of 2014, increasing a 20% with respect to the total volume of sales of the same quarter in 2013 [3]. Tablets have also experimented a 24% increase in the worldwide sales between 2013 and 2014 and forecasts predict an increment of 49% from 2014 to 2017 [4]. With all these results obtained from market analysis through the last years, predictions expect the total number of mobile phone users to be around 6.2 billion (12.1 billion adding also tablets) by 2018, a figure that accounts for almost 84% of the world population [5]. As a result of the aforementioned data, smartphones and tablets are considered as the main means to get to a high percentage of society, being the cradle for the development of new applications in an endless number of sectors.

Making use of the unique features of these devices (camera and big screen), augmented reality (AR) applications have experimented a fast growing in the last years. In this type of applications, information about the real world coming directly from the camera of the device is combined with artificial information (it can be either real or virtually created information) and displayed together on the screen. Virtual information has to be registered in three dimensions with respect to the real world due to the fact that, as the user moves the device, the augmented information must be updated accordingly on the screen of the device [6], [7].

This paper presents a new AR application for smartphone and tablets with art museums exhibiting paintings as the main targets. The development of this application has been carried out within the 7th-framework project INSIDDE [8], whose main objective is unveiling unknown features in paintings

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(hidden paint layers, underdrawings, brushstrokes, etc.) by using a THz scanner so as to enhance the access to cultural resources. Although the THz images obtained are later used by the application to provide hidden details about the paintings, it is important to remark that the functionality is not restricted to these images and other alternatives (infrared, X-rays, etc.) can also be used.

II. DESCRIPTION OF FUNCTIONALITIES

The application described in this paper is aimed at fostering the attendance to museums by bringing art, in particular paintings, closer to citizens. This is achieved by means of explicative and interactive tools that use AR thanks to the cameras and big screens present nowadays in smartphones and tablets. Among the tools included are a detailed description of the painting, an audio guide, a localization of important parts and the overlapping of images for unveiling hidden details.

The functioning of the application is really straightforward, a fact that has been given high priority when developing the application in order not to be only focused only on high-tech level users. Once the application is executed, the camera is enabled and the user only has to aim at the painting and it is automatically identified. After the identification, additional information is shown on the screen, highlighting important parts registered to the actual position of the painting on the screen.

The user has also the possibility of accessing the text information and the audio guide through several menus as well as displaying different images of the painting (infrared, THz, X-rays, etc.) registered to the actual position of the real painting on the screen of the device, having the possibility of modifying the transparency. It is important to remark that the application does not have to capture the entire painting to track it, an aspect that is important when being at busy museums in order to get rid of the problem of partially occluded scenarios. Furthermore, the application automatically crops and resizes the overlapped images in real time in order to fit perfectly to the original artwork depending on the user position. An example of the recognition and tracking system in a preliminary version of the application is represented in Fig. 1.

The images revealing details of the paintings underneath the surface can be obtained by means of using electromagnetic waves in different windows of the spectrum (infrared, THz, ultraviolet, X-rays, etc.) due to their ability to penetrate the outer layers of the painting. These images are stored on the handheld device once the application is installed and are used for augmenting the real world information.

It is worth mentioning that, although there are other available technologies for paintings identification (use of beacons or other sensors that base the identification on the user position, QR codes or other tags), they require the installation of infrastructure, being more expensive than the proposed solution and not permitting the overlapping of images or the selection of important parts through an AR application, reasons why they have been discarded for the implementation.

III. TECHNOLOGIES USED

The INSIDDE AR application has been designed under the multiplatform game engine Unity3D [9], so that it can be easily compiled and exported to be executed not only on the actually leading operating systems (OS), i.e. Android and iOS, but also on Windows Mobile and Blackberry. This implies an even higher depth of penetration, making it accessible for almost everybody. Unity3D has a built-in Integrated Development Environment (IDE), very strong in the real-time rendering of digital objects.

The architecture of the proposed solution, grouping features and technology, is schematically shown in Fig. 2. The AR Software Development Kit (SDK) selected was Qualcomm QCAR Vuforia [10]. Even though this is not an open source solution, it can be still used free of charge, offering a huge performance and very easy integration with Unity.

Vuforia uses computer vision techniques to recognise and track planar images (image targets) in real time. Its registration algorithm permits positioning and orienting virtual images in relation to real objects when these are viewed through the camera of a smartphone or tablet. The virtual image tracks the position and orientation of the painting in real time, making possible its overlapping and, hence, giving the appearance that it is part of the real world scene.

Vuforia also provides the Vuforia Target Manager (VTM) for processing and evaluation, where the target images (the images of the paintings that want to be detected) have to be uploaded following the corresponding directives [11], [12]. After this process, the VTM generates a data representation of the image features together with a rating of the target's expected detection and tracking performance based on the features of the uploaded image. This data representation will be embedded in the device database and will be used to identify the painting.

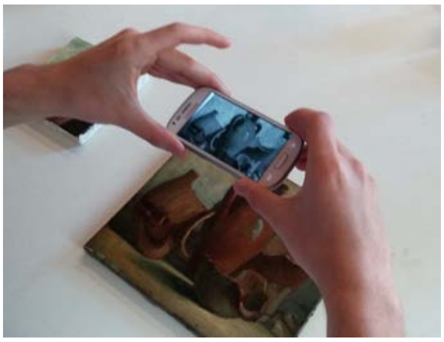

Fig. 1. Identification and tracking in the first mock-up version.

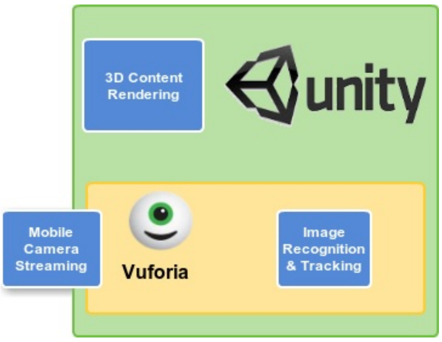

Fig. 2. Prototype architecture.

In the case of the INSIDDE AR application, the processing for the recognition of paintings is carried out locally by means of using device databases, directly installed on the smartphone or tablet together with the application. Among the benefits of this type of processing with respect to the cloud databases counterpart are that it does not generate data consumption, the query times are faster and it supports tracking of multiple targets simultaneously.

IV. PROTOTYPE DESIGN

The design of the graphical user interface has been based on an incremental approach with continuous feedback provided by end users in order to enhance their experience. The final results shown in this paper have been achieved after several mock-ups and their corresponding modifications.

The developed application is made of different screens that will be carefully explained within this section together with their transition map. Right after the moment in which the user runs the application the splash screen shows up, displaying a background of the INSIDDE project until the content is completely loaded.

Once the application is ready to be used the home screen appears automatically, from which the user can access the main screen, find information related to the application or end its execution. If the user enters the main screen the camera of the smartphone starts working. From that moment on he can aim at the painting he wants more information about and, as soon as it is recognised, an icon appears in the upper left corner in which the different images available (infrared, THz, X-rays, etc.) can be selected to be overlapped on top of it. Additionally, red points are registered to the position of the painting and when one of them is touched an information box will emerge offering additional details about it. The goal of this resource is making apparent results from research studies or highlighting specific features that are often neglected in the official guides.

Furthermore, from the main screen the user can also have access to additional functionalities once the painting is recognised by touching on the (≡) icon that is displayed on the top right corner of the screen. This menu displays information about the author, history, chronology, main characteristics, etc.

Fig. *3* shows the author information tab, the main screen and the menu. Inside the author tab the user can also play an audio track with additional explanations. In the main screen, it is important to note how the important parts are registered to the actual position of the painting on the screen.

V. EXPERIMENTAL RESULTS

In this section some practical results after finalising the phase of implementation of the AR application are going to be detailed. The results shown here were carried out using two smartphones running on Android, namely, a Samsung Galaxy S3 mini and an LG G2, although other smartphones and tablets operating under other OS were tested with successful results.

Two screenshots of the application running on the LG G2 are depicted in Fig. 4. In the image on the left the painting is already recognized by the application. The user has the possibility of knowing easily that the recognition has finished

Fig. 3. Author information, main screen and menu.

due to the fact that an icon appears on the top of the painting. When touching this icon, the user can select between the different images available for overlapping, typically infrared, THz or X-rays. In the image on the right the result after selecting an X-rays image is shown. In this figure the good alignment between the real and the virtual pictures can be clearly seen. In this state, the user would have already access to the different menus (top right corner) and the most interesting features of the painting (red dots).

It is important to note that the tracking system keeps working when the user gets closer to the painting and tilts the phone or when the camera of the device cannot capture the entire artwork. Even under these circumstances, the tracking algorithm performs with good results, confirming that the selected system is more than appropriate for its usage on museums, where the presence of numerous groups of people can occlude partially the visualization of the artwork. The overlapped virtual image is cropped and adapted to the actual size of the real painting perceived from the screen of the device depending on its relative position with respect to the artwork. The aforementioned features can be clearly seen in Fig. 5.

As far as the results assessing the performance of the application are concerned, in all cases the time needed for

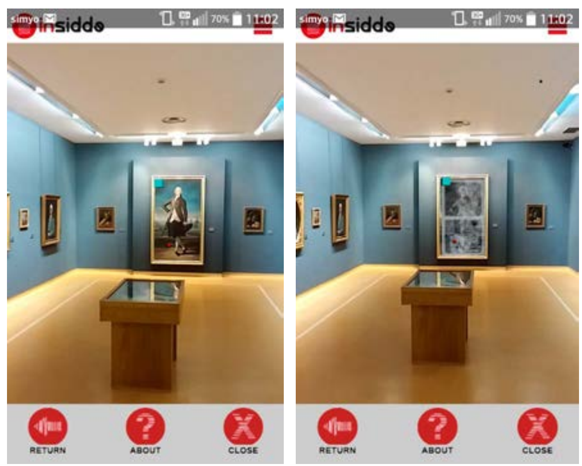

Fig. 4. Screenshot of the recognition and overlapping of X-rays.

painting identification is kept under one second. The tests carried out in the Museum of Fine Arts of Asturias show that the maximum distance for the recognition system to work properly is between 4 to 5 times the smaller dimension of the painting, although it is important to remark that this value depends highly on the quality of the camera. Once the painting is conveniently recognized, the tracking system allows distances up to 13 times the smallest dimension of the painting.

The application has been tested on 11 different paintings with successful results. All the paintings were conveniently recognized with the exception of one, due to the fact that its distinctive features and quality where not sufficient for the VTM, that rated it with zero stars (with five stars being the maximum). The rest of the paintings obtained ratings from two to five stars.

VI. Conclusions

In this paper an AR application designed for smartphones and tablets has been presented. The application makes use of a recognition and tracking system that enables the automatic identification of real paintings just by aiming at them with the camera of the device. Once a painting is recognised the user has access to a great amount of related information such as the author, history or chronology. Furthermore, the most interesting points are highlighted over the screen so as to indicate the parts of the paintings where the user has to pay more attention on, describing features that are not included in the official guides. The developed application makes use of images of the painting obtained by using different windows of the electromagnetic spectrum (infrared, THz, ultraviolet, X-rays, etc.) due to the capacity of this waves to penetrate through the outer layers and unveil possible underdrawings present underneath the surface. The user can pick one of the available images to be overlapped on top of the real artwork, giving additional details about it. Finally, audio guides are also included, permitting the concentration of a great amount of information in one single device and, therefore, getting rid of the typical bulky devices and leaflets available at museums.

The proposed solution has the clear advantage of not making use of the data connection of the handheld device, making it more appealing to users. As far as the museums are concerned, the no need of installing additional infrastructure and the easy inclusion of new resources contribute to achieve a cost-effective and scalable solution, aspects of paramount importance for its acceptance and subsequent deployment.

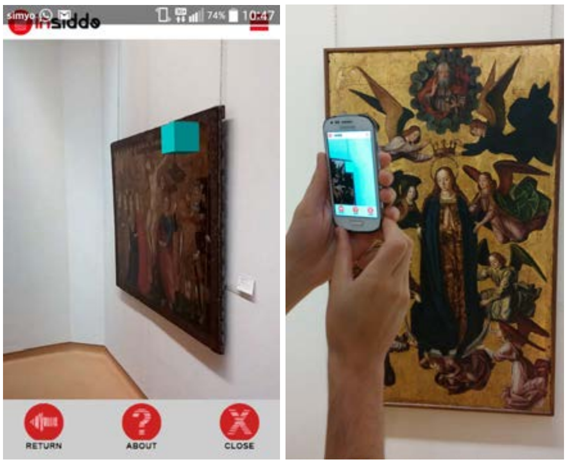

Fig. 5. Example of the application performance.

The obtained results confirm the suitability of the proposed approach, demonstrating that the paintings are recognised under a great variety of different conditions, with a very stable real-time tracking, providing this way an excellent user experience. Furthermore, as the recognition system is based on multiple features of the canvas, dealing with large paintings and tracking partially occluded artworks is not at all a problem.

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