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Augmented Reality and UAVs in Archaeology: Development of a Location-Based AR Application

Maria Concetta Botrugno, Giovanni D'Errico, Lucio Tommaso De Paolis

Department of Engineering for Innovation - University of Salento, Lecce, Italy,
{mariaconcetta.botrugno, giovanni.derrico, lucio.depaolis}@unisalento.it

***Abstract* – In addition to the current use of Unmanned Aerial Vehicles in archaeology, oriented to rebuild the historical evolution of an archaeological area by using aerial photogrammetry and relief of archaeological objects, is possible to consider the fruition through augmented reality. By using jointly UAVs and augmented reality, it is possible to explore sites which are not often directly accessible from the user and from different perspectives, by providing various types of contextual information (3d models, textual information, etc.) and directly on site. This work deals with a feasibility study for the development of a location-based AR Android application supporting the fruition of a given archaeological site from an aerial perspective, by exploiting UAVs and augmented reality. The main contribution of the work was the integration between the Wikitude SDK augmented reality framework and the DJI Mobile SDK and led to the development of DJIARcheoDrone, a first prototype of the application.**

I. INTRODUCTION

The safeguard of the historical and artistic memory of the world cultural heritage has become in recent years the center of discussions, even on interdisciplinary intervention areas, because the perception of a progressive and irreversible depletion of this heritage is growing. The evolution of technology and the possibilities of interconnection in real time and anywhere offered by mobile technology provide an important bridge to the valorisation, the protection, and even the prevention of degradation.

In the last few years, technologies supporting cultural heritage include UAVs (Unmanned Aerial Vehicles), i.e. remotely piloted aircrafts without human pilot on board that provide an important contribution to the reconnaissance, interpretation and knowledge of the state of places.

In addition to the current use of UAVs in archaeology, oriented to rebuild the historical evolution of an archaeological area by using aerial photogrammetry and relief of archaeological objects, is possible to consider the fruition through augmented reality. This technology allows extending the observed reality without replacing it with a completely synthetic one, presenting a world in which real and virtual objects exist simultaneously.

UAVs and augmented reality are part of the large technological investments for the near future. A recent research conducted by Coleman Parkes Research reveals that both technologies will be an integral part of workstations by 2036 [1].

In addition, the emerged data from the report published by WinterGreen Research trace the business growth prospects of UAVs industry from a starting value of $600 million in 2014 up to $5 billion in 2021 [2]. These technologies have a strategic role in many application contexts, but a real bet for the future focuses on their synergy.

The aim of this work is to extend the current boundaries about the use of UAVs in archeology, with reference to improving the user fruition of the archaeological heritage, by combining both the advantages of aerial exploration and augmented reality.

II. PREVIOUS WORKS

The growing development of computer technologies and their involvement in the cultural heritage field not only helps to preserve sites of historical importance at disappearance risk, but it also allows artworks valorization and the improvement of the user experience. In particular, this improvement can be facilitated by technologies such as virtual and augmented reality, which enable to emotionally involve the visitor and increase his level of attention, thereby making easy the learning of useful and precious information regarding an artwork, a monument or an archaeological area.

Several projects are available in literature, where virtual reality appears to be an important tool for expanding and spreading the historical view of cultural heritage, traditionally limited to only a few professionals, scholars and researchers. De Paolis et al. [3, 4, 5] present the reconstruction of a town in the Middle Ages in order to develop a multi-channel and multi-sensory platform for the edutainment in cultural heritage. A digital didactic game oriented towards the knowledge of medieval history and society is proposed and it has permitted a didactic experimentation whereby simulation is considered as a precious teaching support tool. The educational game has prompted students to participate in and experience in a simulated and immersive environment of a town in the Middle Ages in order to connect the recreational actions, and to critically discover roles, functions and actions referring to Medieval life.

Vecchio et al. [6] propose the use of augmented reality and cloud computing technology in order to enrich the scenes of sites with a relevant cultural interest and improve the users cultural experience during the sightseeing of a city of art.

In archaeological field, augmented reality is used both as a tool for enhancing archaeological heritage and improving the visitor's fruition [7, 8], as well as a tool useful for archaeologists in excavation and analysis works [9, 10].

The joint use of augmented reality and UAVs currently responds to multiple needs, ranging from interactive videogames production [11] to improvement of the flight fruition experience, with the possibility to benefit of a first-person view (FPV) experience, as if UAV camera was a real extension of the user view. The most innovative solutions in this regard include the Epson MOVERIO BT-300 smartglasses, which allow the user piloting and keeping an eye on the aircraft, and enjoying at the same time of an augmented vision of the aerial images received from on board UAV camera [12].

Furthermore, this joint use involves the archaeological field, where until now the use of these devices was predominantly limited to the relief of archaeological objects [13] and aerofotogrammetry [14]. In this regard, the experiences investigated in literature still focuses on the videogames world as a useful educational tool to bring above all young people closer to art and cultural and archaeological heritage [15, 16].

III. WORK HYPOTHESIS

A. Methodology

This work deals with a feasibility study for the development of an Android application for supporting the fruition of a given archaeological site from an aerial perspective, by exploiting UAVs and augmented reality.

A first and relevant choice involved the tracking methodology to be adopted for the scenario under consideration. The reference scenario is the outdoor one, where the complexity of a marker-based tracking shall be added to the objective difficulty of a markerless approach based on image recognition, because the environment is not prepared and dynamic, and requires a preliminary collection of a large set of scene photographs at different angles to allow a correct and continuous tracking.

Although some solutions available in literature are oriented towards a hybrid approach, there are several research lines exploiting a tracking based on GPS and inertial sensors [17, 18], which represents the working solution adopted here, thanks to the current availability of position and movement sensors on board the most of UAVs on the market. The choice seems to be advantageous in terms of simplicity and ease of use, independently of changes in lighting, atmospheric conditions, and the environment.

B. Unmanned Aerial Vehicle

The choice of the UAV device that best fitting with project requirements was preceded by a survey phase oriented to choose, among all UAV devices currently available on the market, the product closest to some specific features, including the availability of a development software supporting both Android and iOS, the presence of a GPS receiver and a set of sensors on board, the remote video control, and the compatibility with augmented reality visors. Its important presence on the market and its consolidated use in the examined research projects oriented the choice on DJI devices and, specifically, on the Phantom 3 Professional model.

The remote controller allows an easy and stable aircraft piloting and the camera rotation only for pitch angle.

DJI Mobile SDK, compatible with both Android and iOS systems, is a software development kit provided by DJI in order to give developers the ability to manage all the aircraft potentiality, by developing customized mobile applications. Application development is simplified, because the software development kit takes care of the most of low-level functionality such as flight stabilization and communication between UAV and controller.

C. Augmented Reality Framework

In the choice of the augmented reality framework were taken into account some requirements in terms of compatibility with the Android operating system, specific support for a tracking based on GPS and inertial sensors, and 3D model registration in outdoor scenarios.

Trying to meet all these requirements by keeping a good generality level in the choice, the emphasis was given to the Wikitude SDK framework [19], that represents a multi-platform (Android, iOS, and Smartglasses) augmented reality mobile application library and currently supports location-based, marker-based and markerless tracking (Natural Feature Tracking and SLAM).

D. The Roman Pier of San Cataldo

As archaeological site to be used as scenario in the testbed phase, we focused on the ancient port of Lecce called "Adriano Pier", at San Cataldo. This site has been a great historical interest for the territory in the 2nd century A.D. and it is still possible to admire some original blocks, partly clearly detectable out of the water and partly submerged, and completely covered by marine vegetation.

IV. DJIARCHEODRONE PROJECT

The software project is only made up of an Android mobile application, which runs on a mobile device connected to the UAV remote controller; the interacting systems are two, i.e. the Mobile Device and the DJI Product (consisting of UAV and remote controller in cascade systems). The mobile application uses first of all the DJI Mobile SDK and the Wikitude SDK, and finally the Android libraries. In addition, the connection between mobile device and remote controller is via USB.

Fig. 1. Augmented ArcheoDrone: software project

A. *Integration between Wikitude SDK and DJI Mobile SDK*

The integration work is based on four points: connection to the UAV, decoding of the video stream coming from the camera of the aircraft, telemetry data reception, and redirection of each of these components into the augmented reality experience.
In figure **??**, a simplified version of the application class diagram is proposed. The main class is represented by the activity *MainActivity.java* which, on the one hand, interfaces with the logic of initializing, managing, and presenting AR experience and, on the other, with the classes allowing dialogue with the DJI Product, in order to receive and manage the external inputs. The connection to the DJI Product is performed by an application class, *DJIARcheoDroneApplication.java*, also responsible for monitoring any possible change in connectivity.
Starting with the sample code provided with the DJI Mobile SDK for Android [20], the entire logic for receiving raw video data, parsing, decoding, and rendering video images is inserted into the two classes *DJIVideoStreamDecoder.java* and *NativeHelper.java*. In particular, the first one represents a listener: when this class is instantiated, new raw data coming from the UAV camera can be received, analized, and transformed.
The ffmpeg library identifies syntax and semantics for the bitstream in accordance with the H.264 format, set as a contextual codec during the library initialization.
For hardware decoding, the Android *MediaCodec* class was used in order to access device low-level codecs and was configured through a surface parameter, on which decoded frames will be rendered.
In order to obtain updated values for telemetric parameters with reference to latitude, longitude, and altitude, a dialogue with the FlightController, the UAV on-board computer, must be established. This can be done by using *DJIFlightController*, a DJI class containing a mapping to all on-board computer components, which allows reading both GPS and barometric altitude values at a frequency of 10 times per second.
Yaw, pitch and roll, the three rotation angles with respect to the UAV main axes, can be obtained by querying the *DJIGimbal* class, which allows the full UAV point of view control.
The core component for wikitude sdk is the computer vision engine, which is accessible only through dedicated APIs offered by Wikitude (Native and Javascript API) and deals with the management logic of the main AR process stages, from tracking to registration.
By default, the internal input values coming from the mobile device are used. One of the most important classes in the Wikitude SDK is *ArchitectView*, a views container made up of an OpenGL ES View, which contains the internal video stream and the augmented content, and a Web View, made up of an HTML page with a transparent background.
The goal is to access to Wikitude Engine through the features provided by both Wikitude Android SDK API and plugins, and redirect input values by injecting the "external" ones coming from the UAV (video stream coming from the UAV camera and telemetry data) into the framework. The video stream, in its default configuration, can come from any of the integrated mobile device cameras. In order to receive this stream from another source, a special plugin was used, developed starting from the Input Plugins API provided by Wikitude.
In the context under consideration, the plugin was exploited in order to exclude rendering of the internal video stream from the architectView, by switching off the relative view layer into the container. The video stream coming from the UAV is rendered by MediaCodec directly into a SurfaceView, which will be superimposed on architectView in the views composition (figure 2).

By using the ArchitectView setLocation() method, you can redirect geo-localization parameters by replacing the values provided by the embedded GPS in the mobile device with the values coming from the UAV.
Regarding sensor values redirection, Wikitude SDK does

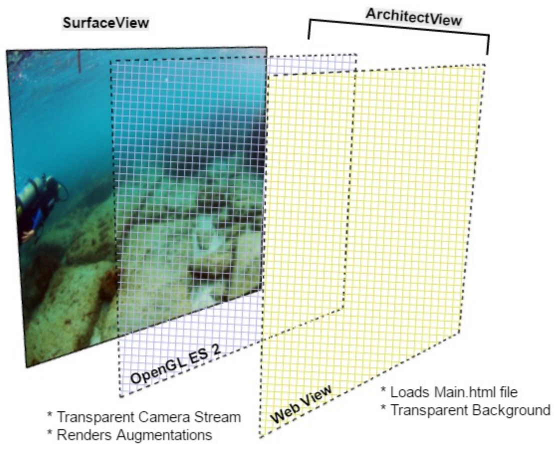

Fig. 2. View composition after integration

not offer any method to notify alternative values for the yaw, pitch, and roll angles provided by the sensors to the Wikitude Engine. This represents the greatest issue encountered in the integration work.

B. Augmented Reality Experience

Wikitude Javascript APIs allow writing cross-platform augmented reality experiences, called Architect Worlds, heavily based on web technologies (HTML, Javascript and CSS).
The augmented reality experience allows the user of an archaeological site visualizing a series of contextual information (superimposed on the aerial perspective of the real scenario) near a specific point of interest. The virtual contents will appear after the touch of a specific placemark, related to the desired point of interest and superimposed on the real scene. Once a placemark is selected, a panel containing textual information will appear on the right of the screen, in addition to a series of buttons enabling to choose the type of content to display.

The visitor will be given the opportunity to visit the web site about the point of interest and enjoy other augmented reality contents, such as a picture slideshow, an audio guide and a video. In particular, the video content will offer a virtual tour within the 3D scenario showing the point of interest in the its ancient splendor.
The application is addressed primarily to the visitor user and the gradual improvement of his fruition experience of the historical-archaeological site. Let us imagine a scenario in which users are able to enjoy a truly flight experience in augmented reality, suitably assisted by an operator authorized to pilot the UAV in the overflight operations of a given site (figure 3).
Furthermore, in the archaeological field, this application would also be a valid support for the scientist, who could take advantage in the aerial reconnaissance surveys from a whole range of augmented information that helps him, for example, in the study of stratified evolution of the site in its various works of finding.
Huawei MediaPad M2-801L tablet with Android Lollipop 5.1.1 has been used for the tests of the application.

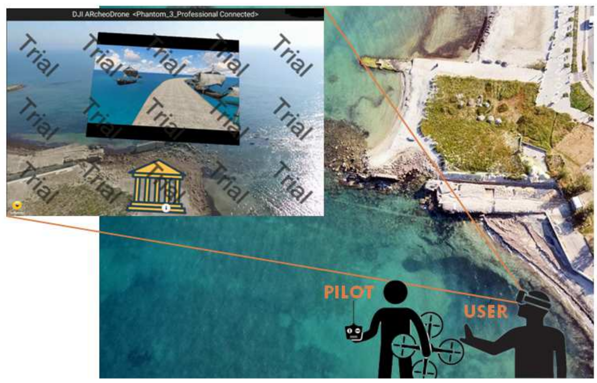

Fig. 3. DJARcheoDrone: user AR experience

V. CONCLUSIONS AND FUTURE WORK

The carried out tests confirmed the effectiveness of the fruition experience of an archaeological site in augmented reality from an aerial view. Although the location-based approach suffers from the limits regarding GPS and sensor inaccuracies, it is simple and portable, allowing the use of the application for any kind of point of interest, independently from contextual conditions (lighting, atmospheric conditions, changes in environment).
Next steps of the research will be oriented to explore other tracking techniques such as hybrid ones that exploit pattern recognition in addition to the use of GPS and inertial sensors, in order to improve registration accuracy and enable even more complex augmented reality experiences, such as the superimposing of 3d models directly on the scene.
Another step will be to extend what is designed for Android systems even to iOS systems, allowing the use of DJIARcheoDrone even on iPhone and iPad devices.
Finally, along with the announced partnership between DJI and Epson, a further future development of the work will be to include the use of the Moverio smartglasses to improve the immersive flight experience in first person view by using augmented reality.

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