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Exploring Pisa Monuments Using Mobile Augmented Reality

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***Abstract*—**Augmented Reality (AR) has taken a big leap with the introduction of mobile applications which co-locate bi-dimensional (e.g. photo, video, text) and tridimensional information with the location of the user enriching his/her experience. This study presents the advantages of using Mobile Augmented Reality (MAR) technologies in traveling applications, improving cultural heritage exploration. We propose a location-based AR application which combines co-location with the augmented visual information about Pisa monuments to establish a friendly navigation in this historic city. AR was used to render contextual visual information in the outdoor environment. The developed Android-based application offers two different options: it provides the ability to identify the monuments positioned close to the user's position and it offers location information for getting near the key touristic objectives. We present the process of creating the monuments' 3D map database and the navigation algorithm.

***Keywords*—**Augmented reality, electronic compass, GPS, location-based service.

I. Introduction

THE usage of smartphones has become a common human activity, and with the large number of traveling applications (which is also constantly increasing), there is an ardent need to use new technologies such as AR in order to enrich these services. AR-based applications overlay images or other important information in real time within a live video stream [1]. AR has been used successfully in training and teaching contexts [2], [3], and even in the cultural heritage area [4]-[6]. In order to visualize the 3D cultural objects of interest [7], different methods have been used including: CAD tools combined with 3D meshes [8], creating object panorama [9], or augmented objects through photogrammetry or reconstruction [10]. These applications can be very revealing, especially when the studied objects are damaged beyond reconstruction [11], like the one used for visualizing images drawn in prehistoric caves that can no longer be seen without being enhanced [12]. AR applications developed for smartphones or tablets are often used for offering travelers a more richer and wider experience, by providing, e.g. an immersive tour [13], [14]. In order to preserve and protect the cultural heritage, AR applications are used to collocate in the real environment historical buildings that have been damaged [15]. They are very useful, especially on archaeological sites allowing, for example, to display different augmentation layers belonging to different epochs or civilizations [16]. The visual tracking can be accomplished by applying various methods: using different tracking flows containing robust visual cues of the scene [17] or real-time registration of video-images named "reference images" [18].

In this paper, we present a MAR application, which establishes a friendly medieval city navigation and displays visual information about Pisa monuments. AR techniques have been used to render contextual visual information about the monuments in an easy and intuitive manner. The contribution of the presented paper is related to enhancing the stability of the visual augmentation, which combines a non-optical tracking algorithm (GPS technology) with optical tracking (using SLAM-based markerless methods). This approach allows identifying not only the location of points of interest near the user, but also potentially useful information about monuments features. After the identification phase, it displays additional contextual historical information co-located in the real environment.

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II. System Design and Implementation

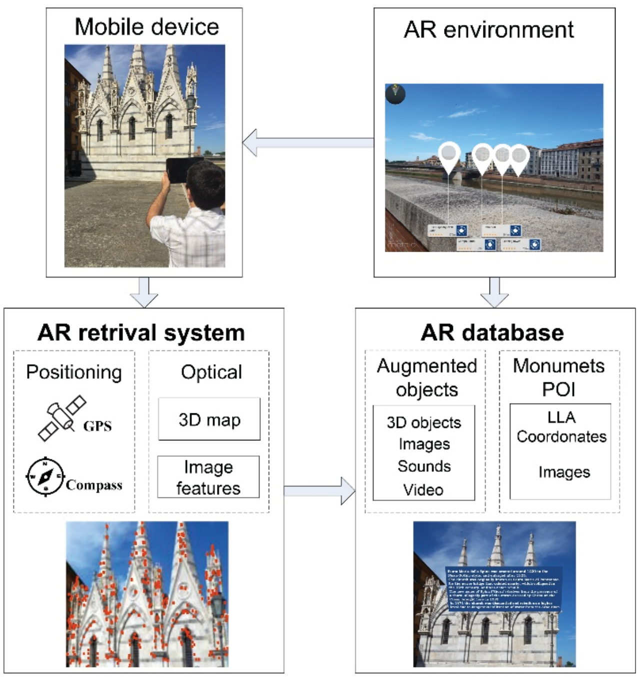


Fig. 1 Architecture of the AR system

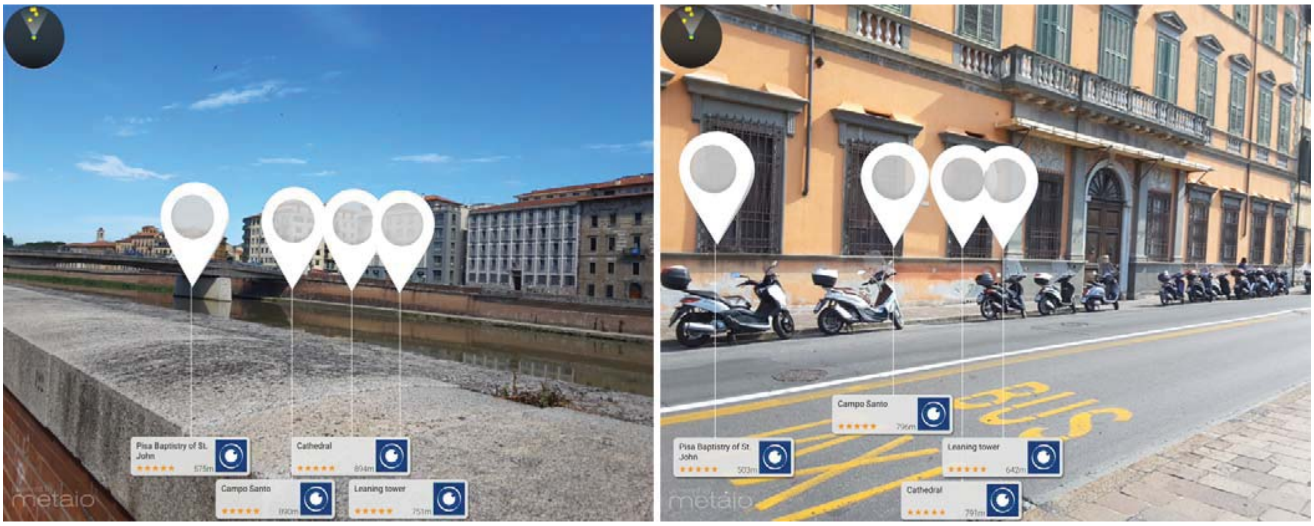
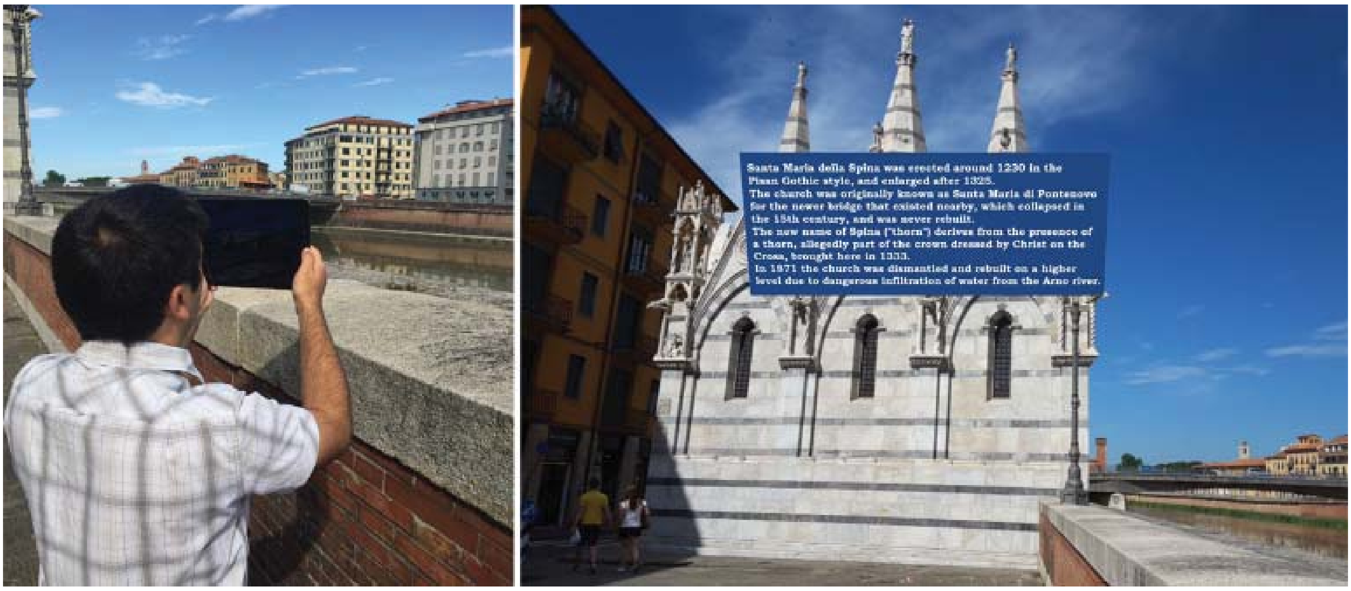


Fig. 2 Images from the real environment collocated with monuments' POI



(a) (b)

Fig. 3 (a) Discovering Pisa monuments (b) AR view of the historical information of Chiesa di Santa Maria della Spina

The system architecture is presented in Fig. 1. In order to augment the user visual perception, a mobile hand held device is used, allowing the combination between real and virtual images and presenting them to the user.

Before the captured live video stream gets displayed on the screen, it is overlaid with additional information. The MAR experience was provided via a Samsung Galaxy Tab S2 on which we developed an Android application based on Metaio SDK library. The application allows two functionalities: (i) discovering the monuments located close to the user's position and (ii) displaying the historical information collocated with existing monuments in the user's view range. The user can choose between discovering AR mode and displaying supplementary monument information (3D model, image, sound).

Monuments are indicated on real images acquired from the camera, as Point of Interest (POI). The geo position of the POI virtual objects is defined by using the latitude, longitude, and altitude (LLA) format. A radar feature was used to display the location of the monuments and the current field of view of the user (Fig. 2). In order to determine location and direction of the user, the GPS and digital compass sensors from the smart mobile device are used.

Supplementary information about the monuments located in the view area of a user are provided by means of a "billboard", an image whose positional data are calculated based on information retrieved by means of the Visual SLAM algorithm provided by the Metaio SDK (which we used to setup the application). The mechanism makes use of 3D maps, which are basically clouds of points identified based on some visual cues from the image.

These are the steps needed to setup the algorithm: (i) first, a database containing the 3D maps is built. These 3D maps are recorded at different locations for each monument (Fig. 3 (b)). In this way, we can recognize different monuments based on their specific 3D map; (ii) an image tracking configuration file based on the previously developed database, is created and stored in a .xml file; (iii) the tracking configuration file is loaded into the MAR app, and the virtual supplementary information on the recognized image is registered by setting the location and scale relative to the camera transformation matrix.

III. Test Case

In the developed application, we included the main Pisa monuments existing in the city center (Leaning Tower, Campo Santo, Cathedral, and Pisa Baptistery of St. John). The GPS location of the monuments (latitude and longitude coordinates) was added to the MAR app database:

- Pisa Baptistry of St. John: lat: 43.72328687202896; long: 10.394156724214554)
- Cathedral: (lat 43.72326361127628; long: 10.395875349640846)
- Leaning tower: (lat: 43.72295928226347; long: 10.39663977921009)
- Campo Santo: (lat: 43.72399680524001 long: 10.394892655313015)

Users head the camera of their mobile device towards a direction, and based on their location, the POIs located in the area are be displayed on the screen (Fig. 3 (a)). When one monument is located close to the user's view area, corresponding supplementary information (3d model, text, image) is displayed co-located with the monument. In Fig. 3 (b), the AR view of the historical information of Chiesa di Santa Maria della Spina is presented.

Chiesa di Santa Maria della Spina is a small church erected around 1230 in the Pisan Gothic style, and enlarged after 1325. The particular name of the church (Chiesa della Spina, "thorn") derives from the presence of a thorn, allegedly part of the crown dressed by Christ on the Cross, brought here in 1333. In 1871, the church was dismantled and rebuilt on a higher level due to dangerous infiltration of water from the Arno River [19]. This information is displayed when the user stands in front of Chiesa di Santa Maria della Spina and points the camera towards the monument, based on the features identified in Fig. 4.

Using the application, it is also possible to display videos related to the monument currently augmented. The process uses the same tracking configuration to display AR content, but in this case, we use a video instead of an image (Fig. 5).

Fig. 4 SLAM feature map for Chiesa di Santa Maria della Spina

Fig. 5 Displaying video content with AR

IV. Conclusion

In this paper, a mobile application, which makes possible discovering surrounding monuments by co-locating visual and 3D information in the location of the user, was presented. The advantage of the presented AR application is the possibility to enhance the tourism experience by providing the user the possibility to get familiar with the cultural heritage assets located in unknown places. The user points the mobile device in the direction of a monument, and the system co-locates additional information about existing cultural heritage entities of interest located nearby. Further research will be focused on the evaluation of MAR app for history learning. Also, we plan to add to the application a functionality which will allow linking the monuments POI to related Wikipedia articles and YouTube videos.

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