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AUGMENTED REALITY AS A METHOD FOR EXPANDED PRESENTATION OF OBJECTS OF DIGITIZED HERITAGE

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Abstract. Augmented reality is the latest among information technologies in modern electronics industry. The essence is in the addition of advanced computer graphics in real and/or digitized images. This paper gives a brief analysis of the concept and the approaches to implementing augmented reality for an expanded presentation of a digitized object of national cultural and/or scientific heritage.

1. Introduction of the concept of augmented reality. Many popular definitions of Augmented Reality (AR) exist in the computer science community, but the general idea in this paper is that augmented reality enables an additional perspective via inculcating virtual objects on the real world by a technique that convinces the viewer that the virtual object is a part of the real environment.

For that reason augmented reality is considered like a union between the real and virtual world. In this flow of thoughts we can talk about reality-virtuality continuum, as shown below in Fig. 1, see also [6].

Usually it is considered that objects of the virtual environment maintained by AR are mostly 3D computer graphics models, but most specialists accept another definition, where the virtual reality may consist of 2D computer-modeled

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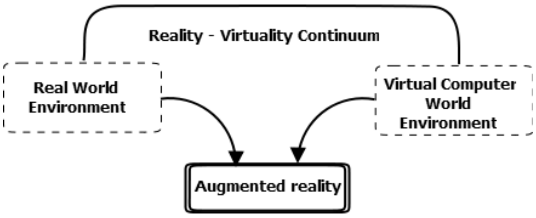

Fig. 1. Reality-Virtuality continuum

objects, text and images. There is a branch in the software industry that presents multimedia content, and visual search capabilities and similar developments are promoted as applications of augmented reality.

Below we describe some concepts and terms, which play an important role in AR information technology.

Reality View – Refers to the video stream produced by a mobile device camera. This is the same feed that the users see when they use the mobile device's regular camera application. The AR application captures images from the video stream, augmenting the live feeds with virtual objects to create an augmented view [1].

Registration and Tracking – Describes the available methods for aligning a virtual object with 3-dimensional co-ordinates in the reality view. For mobile device applications, object tracking involves either location sensors such as GPS, digital compass and orientation sensor (location-based tracking) or an image recognition system (optical tracking) or a combination of the two. Here (and in the text below) under the term orientation sensor we will understand a hardware module consisting of gravimeter and magnetometer.

Virtual Object – Some kind of digital content that is rendered by the AR application and is superimposed on the reality view. Typical content includes 3D models, 2D images, icons and text.

The typical data flow in an AR application is shown in Fig. 2.

In the AR application concept the key stone is an identification and localization of a virtual object, which is a part of the augmented reality. The **tracking module** from Fig. 2 is responsible for identification, where commonly two methods are used: optical tracking known as marker identification and location-based tracking known as a markerless identification.

2. Difficulties in practice of commonly used identification methods. The challenge in the development of AR software is identification and tracking of the registered object. We will comment below on marker and markerless virtual objects identification methods.

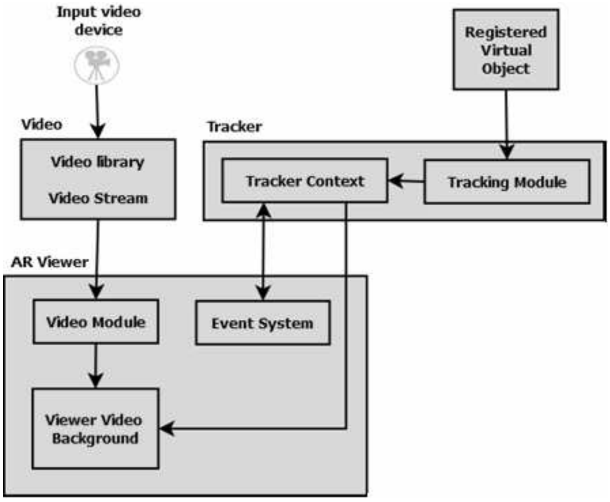

Fig. 2. AR application data flow

The use case of **marker identification** work flow is shown bellow in Fig. 3, see also [2]. The work flow is discussed in the case of the mobile device being a smart phone. The *first step* runs when the AR viewer examines around through video camera. At *step two*, if the picture marked or looked for is in the field of view, the AR software begins the identification process. *Third step* – the viewed picture is binarized and featured. Here the AR software searches the database (DB) to match the featured picture with a previously registered virtual object. If a match exists, then the respective virtual object is counted as identified. The next *fourth step* is important in this case, when the identified virtual object has its own 3D model. At this step the AR software recognizes the marker spatial orientation and establishes a local coordinate system of the model.

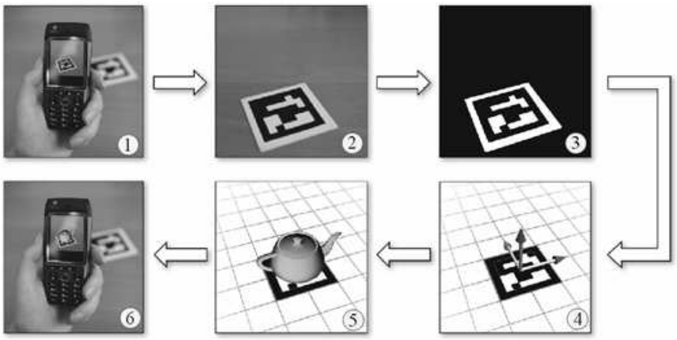

Fig. 3. Marker method identification work flow (taken from [2])

The marker identification is completed at the *fifth step* when the respective 3D model is created with a defined scale, position and orientation. And finally (the *sixth step*), the AR software produces a new video background which does augmented live video feed.

Usually, steps 3 and 4 cause problems in the approach described above via marker identification. The solution of these problems lies in applying efficient techniques for image processing, e.g. gradient approaches for still images or the standard KLT (Kanade-Lucas-Tomasi) approach [7] for video.

The second discussed approach of identification and tracking of virtual objects is **markerless identification**. A case of markerless identification, based on geo-location, is shown in Fig. 4.

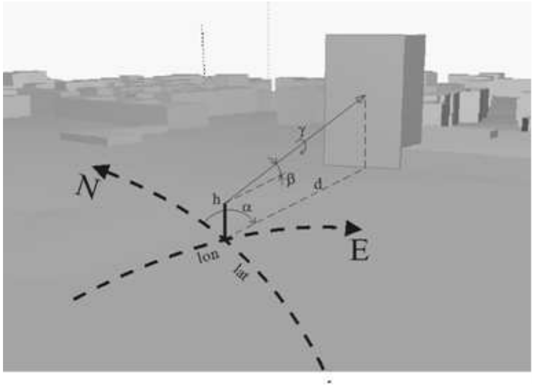

Fig. 4. Markerless geo-location based identification setting (a new quarter of Sofia)

Important steps in the markerless setting are determination of position, determination of the direction of the device's camera optical axis and acquiring the target bounding box for each virtual object of interest. The last is shown in Fig. 4, see the biggest rectangle there.

The current position of viewer's mobile device is indicated in Fig. 4 as ***lon***, ***lat***, and ***h***. Here *lon* and *lat* represent the geographical coordinates, longitude and latitude, and h is the altitude of the device camera over the geoid model surface. Determining the current position of the mobile device is done using the built-in GPS module. A difficulty of this step can be the delay in the initial establishment and the inherent error of this class of devices. It should be noted that the error in altitude may be substantially larger than the error in determining the coordinates.

For this use case, the camera optical axis direction is usually presented by acquiring the so-called Euler angles [3], signed by α, β, γ in Fig. 4. These three angles are evaluated by the orientation sensors (e.g., magnetometer and gravimeter) built into the mobile device. The magnetometer gives the azimuth α (i.e., the orientation to North). The angle β (towards the 'target place') can be determined via the gravimeter, as well as the rotation angle γ towards the horizon.

To acquire the target bounding box of the 3D virtual object model, we propose the application of the so-called ray tracing method. Let us assume that we have access to the DB of the virtual environment, and that the wanted virtual object is defined in this DB by a few planes, each plane P defined by three points P_1, P_2, and P_3, each of them represented in Cartesian coordinates $P_1 \equiv \{x_i, y_i, z_i\}$, $i = 1, 2, 3$. Also the optical axis L of the device camera is defined by two points P_4, and P_5. The task is to determine the points of intersection of the line L with all possible planes P and to verify each of the resulting intersections for falling within defined bounding boxes. The difficulty of implementing this method is the need of intensive computations on-line with the movement of the camera. To solve the problem we propose the matrix approach known from computational geometry, e.g., the intersection point $(x,\ y,\ z)$ looked for can be calculated by equations [4]:

$$\begin{aligned} x &= x_4 + (x_5 - x_4)t \\ y &= y_4 + (y_5 - y_4)t \\ z &= z_4 + (z_5 - z_4)t \end{aligned} \tag{1}$$

where the parameter t is:

$$t = \frac{\begin{vmatrix} 1 & 1 & 1 & 1 \\ x_1 & x_2 & x_3 & x_4 \\ y_1 & y_2 & y_3 & y_4 \\ z_1 & z_2 & z_3 & z_4 \end{vmatrix}}{\begin{vmatrix} 1 & 1 & 1 & 0 \\ x_1 & x_2 & x_3 & x_5 - x_4 \\ y_1 & y_2 & y_3 & y_5 - y_4 \\ z_1 & z_2 & z_3 & z_5 - z_4 \end{vmatrix}}. \tag{2}$$

For the ray $L \equiv (P_4,\ P_5)$ we choose: P_4 to coincide with the optical center of the camera (at a height h above the ground) and P_5 to be along the optical axis of the camera, somewhere in the 3D volume of the whole scene of interest. Of course, the point P_4 is obtained from the GPS sensor in geographical coordinates that should be converted to the Cartesian coordinate system of the selected model in the DB. So, P_5 is directly calculated in Cartesian coordinates according to the currently measured Eulerian angles of the optical axis.

Point P calculated by (1) and (2) is checked for a hit in the 3D bounding box of the object we are interested in the DB, and in the case of Fig. 4, this is a building to whose wall (P_1, P_2,P_3) the camera of the mobile device is focused.

As shown in equation (2), the proposed method calculates determinants of square matrices. In case of intensive calculations it is vital to shorten the time to resolve the determinants of the above equation, without hindering mobile device. As a possible solution in this case we suggest matrix calculations to be transferred for execution by the video core hardware of the mobile device.

3. Expanded presentation of digitized heritage objects. A promising application of the AR technology is in the area of digitization of cultural and scientific heritage. Both methods for identification of virtual objects described above are used in the expanded presentation. The marker identification method can be applied in museum exhibitions, or for research purposes. As shown in Fig. 5 below, a virtual object modeled by means of 3D computer graphics is available in a laboratory environment, i.e., without its physical presence. The model can be arbitrary rotated, scaled, moved, i.e., arranged in an appropriate environment. The technology allows the construction of a virtual environment by several independent models of virtual objects.

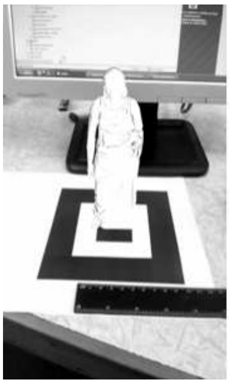

Fig. 5. The statue modeled over the centralized square in the image is a product of AR technology (produced via the AndAR Model Viewer software)

The second identification method of Augmented Reality technology, i.e. the markerless identification, as applied to digitized heritage is useful in field of archeology.

As shown in Fig. 6, a computer model represents a virtual reconstruction of the ancient arena, an authentic object of contemporary Italy. In this case the implementation of markerless location based identification helps the viewer to see

Fig. 6. Augmented reality in archeology (ruins of an ancient arena from Italy)

the area as it looked in the past. In this application it is preferred for the mobile device to be of a type of computerized glasses.

We organized a software experiment, the purpose of which is to assess the impact of possible imprecision of orientation sensors, especially of magnetometer. For the aims of the experiment the virtual world is represented in a Geo-DB like an on-line accessible 3D model of the Earth's surface. The fidelity criterion to start augmenting is a sufficient matching between the corresponding features of the 3D model relief and the actual images of the real world obtained by the mobile device camera. The observations conducted from several view positions, far away enough from each other, indicate an essential deviation generally associated with the magnetometer and leading to incorrect determination of azimuth of the mobile device orientation. Famous tabular corrections for magnetic declination (i.e., the angle between magnetic North and true North) [5] applied for the territory of the experiment are not sufficient to overcome the observed deviation. To minimize the influence of random factors on the magnetometer, we introduced an extra software module for interactive compensation of the azimuth error.

4. Conclusions. The AR information technology assumes its important place in a field of reconstruction, research and learning of digitized cultural and scientific heritage. There can be expected an increase of the proportion of mobile devices based on expanded presentation applications in near future. This is supported by mobile devices of enlarged hardware capabilities such as faster processors, larger and speedy storage memory, 3D graphic accelerators, etc. In addition, there are many specialized software tools, which allow developing AR applications easily and quickly.

Still, there are problematic places in the sphere of virtual processing, e.g., marker or markerless modeled object identification. The method of marker identification depends on the camera's capabilities and fast image processing algorithms.

The method of markerless identifications depends on the inertial sensors' quality, where magnetometers present the worst problems. And last but not least, the computational power and the implementation of effective mathematical methods are crucial to the ultimate beneficial effect.

REFERENCES

[1] Butchart B. Augmented Reality for Smartphones. A Guide for developers and content publishers. JISC Observatory, TechWatch Report, 2011.

[2] Wagner D., D. Schmalstieg. ARToolKitPlus for Pose Tracking on Mobile Devices. In: Proceedings of the Computer Vision Winter Workshop, St. Lambrecht, Austria, Graz Technical University, 2007, 1–8.

[3] Euler Angles. `http://mathworld.wolfram.com/EulerAngles.html`, November 2014

[4] Line-Plane Intersection. `http://mathworld.wolfram.com/Line-PlaneIntersection.html`, November 2014

[5] Magnetic Declination. `http://www.ngdc.noaa.gov/geomag/declination.shtml`, November 2014

[6] Milgram P., H. Takemura, A. Utsumi, F. Kishino. Augmented Reality: A class of displays on the reality-virtuality continuum. *Telemanipulator and Telepresence Technologie,* **2351** (1994), SPIE, 282–292.

[7] Shi J., C. Tomasi. Good features to track. In: Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR'94), 1994, 593–600.

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