European Journal of Science and Theology, April 2013, Vol.9, No.2, 223-231

VIRTUAL RESTORATION OF DETERIORATED RELIGIOUS HERITAGE OBJECTS USING AUGMENTED REALITY TECHNOLOGIES

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(Received 25 June 2012, revised 5 February 2013)

Abstract

In this paper, an approach for the virtual restoration of the religious heritage objects is proposed. The presented method is based on Augmented Reality technologies, which enable virtual restoration of the original heritage object by co-locating the reconstructed 3D virtual model with the real one. This method gives the opportunity to better perceive the damaged object. The proposed method consists in the following actions: obtain documentation about the damaged heritage object, processing of the documentation, 3D reconstruction of the monument, finishing and completing details, registration of the co-located 3D virtual model. The output of the proposed method is a reconstructed 3D model of heritage object, which can be visualized co-located with the real one by using common equipment such as Smartphone or Tablet PC. The application of the proposed methodology, which is used as a case study, was conducted in Brasov, at the Black Church. The proposed methodology may open new possibilities for the restoration of other religious heritage objects.

Keywords: virtual reconstruction, Augmented Reality, image based modelling, restoration

1. Introduction

There are many religious heritage objects and old relics, for which the restoration is not achievable. For an inexperienced visitor, in case of damaged heritage objects, it will be very difficult to identify or to imagine the original form and details. Virtual reconstruction is a suitable technology that can be applied in these cases. Virtual reconstructions should be defined as those environments where the human operator is transported into a new interactive environment by means of devices that display signals to the operator's sense organs and devices that sense various actions of the operator [1].

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Advances in computer graphics and Virtual Reality (VR) technologies have allowed creation of virtual 3D model that represent real objects at any scale and complexity. The key concept is to create from the pictures, paintings or other historical material of the original object a virtual replica of the damaged heritage object using computer graphics and VR technologies. The reconstructed model then can be displayed in an interactive environment by means of devices like: CAVE-like immersive environments, reality theatres, power walls, holographic workbenches, individual immersive systems, head mounted displays, tactile sensing interfaces, haptic feedback devices, multi-sensational devices, speech interfaces and mixed reality systems [2].

Recently, virtual reconstruction based on VR technologies has been proposed as an improved interface for ancient architecture reconstruction [1, 3-10] monumental paintings of the church [11], completion of facial image in ancient murals [12, 13], restoring content from distorted documents [14] and art restoration [15]. The VR technologies offer several advantages for virtual reconstruction: improve the immersion awareness; high-definition stereoscopic images are obtained; large filed of view; collective visualization; collaboration between several users. The disadvantages of using VR technologies for virtual reconstruction are the high complexity and the usage of expensive devices which limited the applicability of this technology to the consumers.

Augmented Reality (AR) is a relative new research direction that allows creation of an interactive virtual space embedded into the physical word. In order to remove presented VR issues, AR technology allows the creation of an interactive virtual space, embedded into the physical word. Unlike VR systems, in which users are completely immersed in the virtual environment, AR gives the users the possibility to see the virtual objects and the real world coexisting in the same space (co-located). It is the goal of AR to supplement reality rather than completely replace it as in conventional VR applications. The AR technology provides useful information about the environment, enhancing the perception of spatial information and interaction with the real world. The user can interact with the digital objects in an actual 3D space, which is more natural and intuitive. In this way, AR offers the possibility to visualize 3D reconstructed model of the heritage objects co-located with the real environment and provide an efficient and intuitive communication channel for spatial information.

In this paper, an approach for the virtual restoration of the religious heritage objects based on AR technologies is proposed. This method enables virtual restoration of the original heritage object by co-locating the reconstructed 3D virtual model with the real one. The paper is organized as follows: section 2 reviews prior work, section 3 describes the proposed AR-based reconstruction method, section 4 point up the results and section 5 presents conclusions.

2. The research background

Nowadays, there are presented several applications of using augmented reality in virtual reconstruction. In [16] AR technologies are used for virtual 3D reconstruction of ancient frescos paintings, fauna and flora and animated characters from the ancient Pompeii. For the co-location of 3D model in the virtual environment it was used a mobile AR wearable setup with markerless tracked camera. In [17] is presented the development of AR-based personalized electronic guide and tour assistant for the Ancient Olympic Games. The system uses a position-orientation tracking component to display AR reconstruction of the temples and animated characters. The site visitors are wearing AR glasses to see the 3D image display. The disadvantage of this type of display is the low resolution and autonomy.

AR has also been used for the virtual recovery of the deteriorated art object [18], where the correction pattern for restoration is generated from non damaged object's image scanned in advance and projected on the damaged object using a calibrated LCD projector. Although their approach has innovative aspects, this technique can be applied only for the restoration of the discolouring objects of small dimension, and is not suitable to be used for outdoor reconstruction of religious monuments. Recently in [19] are presented two examples of using QR code-based AR system for the three-dimensional reconfiguration of urban places in order to show evidence of 'invisible' architecture.

Considering the virtual reconstruction of the religious heritage objects, there are only presented applications related to monumental painting [11] and temple architectural reconstruction [3-5, 8, 9] using a 3D VR technologies. From the authors knowledge, in the consulted scientific literature there is not presented a methodology for creation of AR-based virtual reconstruction applications. Also, in all these reviewed papers, there is not presented AR-based virtual reconstruction of outdoor religious heritage objects, such as the outdoor sculpture of Black Church from Brasov.

3. Methodology for creation of AR-based virtual reconstruction applications

The AR-based system is composed from files which allow visualization of the co-located 3D model of the reconstructed model and the pattern of the original heritage monument. In principle, the methodology for creation of AR-based virtual reconstruction application could be formulated as to cover the following steps:

(1) 3D reconstruction of the heritage object. This is an important and elementary step in the process development of AR-based application. Actual 3D reconstruction techniques for AR which are suitable for Virtual Heritage applications are: image-based modelling, range-based modelling, image-based rendering, photogrammetric and combination of image-and range-based modelling [20]. For reconstruction of outdoor architecture objects, image based modelling is a technique commonly used. Image-based modelling refers to the use of images to generate the reconstructed 3D model. It is use a mathematical model to pick up 3D object information

from 2D image dimensions or to get 3D data using methods such as shape from shading, texture, specularity, contour and from 2D edge gradients. The advantage of image-based representations is the capability to represent arbitrary geometry. This technique also can handle subtle real-world effects captured by images, but difficult to reproduce with usual graphics techniques [21].

(2) Conversion of the 3D reconstructed model data. The virtual model cannot be loaded in the AR software because there is not standard interoperability procedure. Therefore this step consists in extracting the entire geometric data of the 3D reconstructed model and conversion to an appropriate common exchange file format (for example *.3ds, VRML, X3D, etc.) that can be loaded by general AR framework.

(3) Registration of the 3D virtual model with the existing monument. Registration in AR applications represents a precise alignment of real and virtual objects. This is an essential operation that influences the visual perception of the co-located model and the efficiency of the developed AR application. Marker-based tracking is a common technology used for developing AR applications. But this technology is impractical for outdoor AR based reconstructions, due to the laborious task of having to place markers accurately at various predefined locations. An appropriate solution is to use tracking of textured planar regions using randomized trees based key point classifier for pose initialization and estimation.

(4) Visualisation of the co-located reconstructed virtual heritage object using a physical display device (HMD, Smart Phones or Tablet PC).

4. AR-based virtual reconstruction of the Black Church outdoor sculpture

A prototype AR system for the virtual reconstruction of outside sculpture of the Black Church was developed, to demonstrate the methodology presented above. The Black Church is the main cathedral in Brasov, a city in south-western Transylvania, Romania. It stands as the main Gothic style monument in the country and the largest Gothic church between Vienna and Istanbul. The Black Church had a turbulent history: built between 1385 and 1477 on the site of an earlier church (destroyed by Mongol invasions in 1242), the construction of the Marienkirche was hampered by extensive damage caused by Turkish raids in 1421. The church was given its new name after disaster struck again in 1689, when the 'Great Fire', set by Hapsburg invaders, levelled most of the town, heavily damaged the church, blackening its walls. Restoration took almost 100 years [http://www.brasovtravelguide.ro/en/brasov/sightseeing/black-church.php].

Outside sculptures of the Black Church, during the time, where damaged or totally destroyed (Figure 1). The oldest statue still standing belongs to Saint Peter and can be seen on the Southern part of the church. The church is built of friable grit stones and andesite arranged in cubic shape. That is the reason why the statues placed on the exteriors couldn't survive the time and some of them are missing or were replaced by new ones. The objective of the developed AR-based application was to reconstruct the virtual 3D models of these outside sculptures and co-locate them with the real church.

Figure 1. The 'Black Church', Brasov.

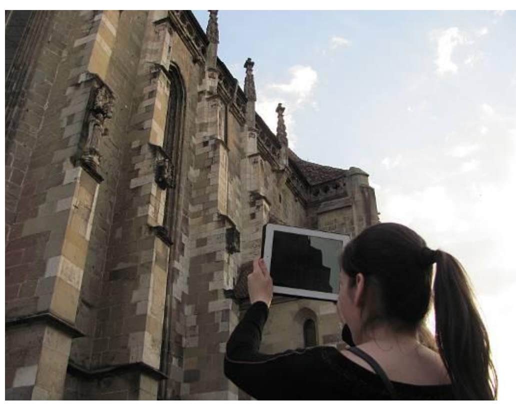

Figure 2. Using Tablet PC for perception of co-located reconstructed 3D model.

4.1. Resources

In order to augment human's visual sense, a physical display device is used allowing combining real and virtual images and present them to the user. Many forms of video display can be used: Head Mounted Displays (HMD), portable displays (like Smart Phones and Tablet PC), monitors and projectors. HMD is a common choice for AR because it is portable, and it is placed directly on the users' visual range. But the use of a HMD is not the best solution to be used for outdoor activities because of the low autonomy and high cost. Technical progress in handheld devices and tablet-PC has opened an enormous potential for development of AR applications due to the. In this research was used a portable AR system composed from a Tablet PC (Figure 2).

4.2. 3D reconstruction of the 'Black Church' virtual heritage models

To create the 3D model of damaged sculpture it was used the image-based modeling technique. In a first step, images of the heritage sculpture were captured. Then these images where processed in order to eliminate the blurry pictures and to enhance the visibility of the heritage sculpture. In order to apply the image-based modeling technique we studied several computer programs available, such as: Autodesk Image Modeler (http://usa.autodesk.com/), Google SketchUp (sketchup.google.com), ARC3D (www.arc3d.be) [22], MeshLab (meshlab.sourceforge.net), PhotoModeler (www.photomodeler.com). For the development of the application, we select the ARC3D program to generate from a set of images the point cloud of 3D geometry and the MeshLab program to generate textured 3D mesh VRML model of the reconstructed object. The specific steps for the reconstruction are: (i) loading the processed images to ARC3D program, (ii) import the resulted *.v3d file in MeshLab program, (iii) select and delete the point corresponding to other objects than the focused outside sculpture, (iv) apply a subsample filter, (v) apply a Poisson reconstruction filter, (vi) apply the texture and convert the mesh in the neutral format Virtual Reality Modeling Language (VRML) (Figure 3).

4.3. Registration of the reconstructed 3D models

Architecture software was created for the visualization of the reconstructed 3D model in the co-located environment (Figure 4). The code written for the AR-based virtual reconstruction system is based on a library called Instant Player (www.instantreality.org). The advantage of using this library is the possibility to integrate various VRML and X3d graphical formats of virtual objects and possibility to create External Authoring Interface (EAI). Registration of the reconstructed 3D virtual model with the church building was developed using the instant reality's vision Generic Poster Tracker module for tracking of textured planar regions. The tracking methods used are randomized trees based key point classifier for pose initialization and a KLT tracker [23]. In order to create an AR application based on this tracking technology, the user has to carry out the following steps: (i) acquire a reference image of the real scenario with the camera used for tracking by using image capturing software (for example the free software IrfanView www.irfanview.com), (ii) perform an offline classifier training phase using the function Generate Poster Tracker of Instant Vision module, (iii) embed the tracker data from the generated *.pm file into the AR application, (iv) co-locate the virtual model on the original church building location by modification of scale, 3D position, and orientation, relative to the camera transformation matrix and save the registration data in a configuration file. Then the user can visualise the co-located virtual sculpture object on the original location using the Tablet PC or laptop display device.

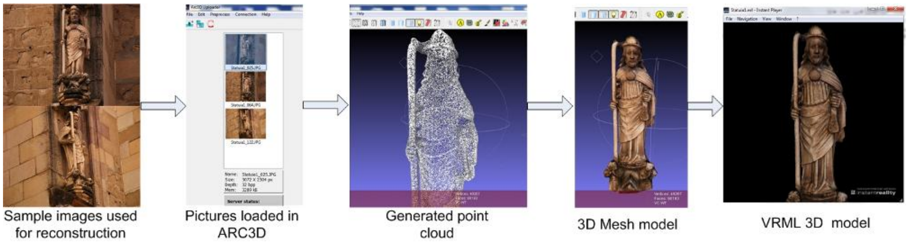

Figure 3. The 3D virtual reconstruction of the 'Black Church' sculpture using image-based modeling technique.

Figure 4. Co-location of the reconstructed virtual model with the 'Black Church' using the developed AR system.

5. Conclusions

In this paper, it was presented the methodology and prototype software system of an AR-based virtual reconstruction system. This approach helps users to perceive better damaged sculptures and to learn about the culture by interacting with a virtual reconstructed environment. Using this system can be made without the need for expensive equipment, because only common computing devices are needed. However, out of these positive results the system has his limitations, since problems can come out when the intensity of the light it is weak, which affects the level of tracking accuracy and make the registration of reconstructed 3D model difficult.

Acknowledgement

This paper is supported by the Sectoral Operational Programme Human Resources Development (SOP HRD), financed from the European Social Fund and by the Romanian Government under the contract number POSDRU/88/1.5/S/59323 for author (1) and by the Sectoral Operational Programme Human Resources Development (SOP HRD), financed from the European Social Fund and by the Romanian Government under the contract number POSDRU89/1.5/S/59321 for author (4).

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