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Original article

ReVitAge: Realistic virtual heritage taking shadows and sky illumination into account

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ABSTRACT

Today's modern organizations are striving hard to trace the beginnings of human civilization and maintain cultural heritage throughout the world; as a result the need for an integrative technique materializing this dream is felt more than ever. Realistic historical buildings in outdoor rendering Augmented Reality (AR) systems require sophisticated effects such as shadows, lighting and the ability to reveal the effect of sky dome illumination on virtual as well as real objects. In this project, the sun position and sky colour are simulated using Julian dating and Perez model respectively. The historical buildings are pre-created using LightWave 3D. An AR system is created using a new marker-less camera setting. The sky illumination is exerted on the virtual historical buildings using a Hemicube Radiosity technique. We have tested the proposed method on Portuguese Malacca heritage building (Melaka, Malaysia) in different places to reveal the auto-adjustment of the system in the case of shadow positioning, lighting and the sky's illumination. The final system could be installed on HMD (head mounted display) or in our device called ReVitAge to show the realistic reconstructed virtual heritage buildings, taking the main outdoor illumination components into account. Throughout this method, listed heritage buildings can be revived in the minds of people from different backgrounds who share the same ambitious dream. It is strongly hoped that this idea can make historical buildings a virtual reality; closer to people's hearts.

1. Introduction

As today's modern organizations are striving very hard to maintain cultural heritage throughout the world and trace the beginnings of the human civilization, the need for an integrative technique materializing this human dream is felt more than ever. Thus, listed heritage buildings can be revived in the minds of people from all walks of life who are interested in this grand dream. Reconstructing virtual heritage buildings can make historical buildings a virtual reality; close to people's heart.

Nowadays, in most historical places and museums, there is a 3D room to show the reconstructed historical objects in virtual environments. However, visiting these objects and buildings in virtual environments suffer from a lack of realism which needs to be addressed.

Augmented Reality (AR) is a technology which is expected to become, without a doubt, a fascinating widespread technology in a multitude of subjects. It has been more than a couple of decades since AR entered computer graphics, and many other fields, to combine real and virtual environments [1–4]. 3D graphics, especially augmented reality, may be used to create a bridge between modern civilization and the past that future generations may forget.

Virtual Heritage in AR is an interactive computer based technology which can be used to achieve visual reconstruction, aiding scholars and educators of traditional entities such as buildings, artefacts and culture [4–7]. This technology preserves delicate historical buildings from natural disasters and vandalism [8,9]. For producing a virtual heritage, there are seven design principles which must be taken into account including high geometric accuracy, high automation level capture of all details, low cost, photorealism, flexibility, portability, and model size efficiency [10].

Augmented Reality makes virtual heritage interactive and more realistic due to the reconstruction of original buildings among real environment objects. Generating a virtual building in real environments enables the user to interact with traditional buildings while recovering some of the ruined parts which will help increase the reality of the ancient culture. Modern users can be connected to the ancient culture and traditional customs through our proposed virtual heritage in augmented reality systems.

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The SIGGRAPH reports that Augmented Reality is one of four attractive topics and they encourage more submissions due to diversity challenges [11]. Augmented reality has been employed in different areas such as training aid for surgery [12,13], maintenance and repair [14], annotation [15], robot path planning [16], entertainment [17,18], surgery [19], military aircraft navigation [20], targeting [21] and cultural heritage purposes [22].

There is a diverse range of historical buildings in the world and most of them have been ruined partially, some even completely. Reconstructing these cultural heritages not only helps getting in touch with the past, but also enhances the appeal for tourists [23].

According to the European Commission's report [24,25] "Computing hardware and software have advanced to a point where it is possible to construct and view models using personal computers." We have taken this further and created a simple device to visit historical buildings through our personal computers.

In this study, we attempted to create a realistic real-time mixed environment. We placed virtual heritage in real environments, taking the sun position and sky illumination into account, with respect to shadows from a given time, date and location. The mixed environments are observed through a simple device named ReVitAge (Realistic Virtual heritAge). ReVitAge controls the orientation of augmented buildings in two different directions; vertical and horizontal. ReVitAge is proposed to overcome the main issue of most marker-less techniques, which are not robust enough.

3D modelling is widely used in Virtual Environments (VEs) and Augmented Reality (AR) which is an integration of virtual environments and Real Environments (REs). An AR-system incorporates more real objects and fewer virtual ones, with the real objects taking a dominant role over the virtual. Furthermore, if a real object is set within a virtual environment, the system is called Augmented Virtuality (AV). In this case, most of the system elements are virtual Fig. 1 illustrates these concepts.

In general, Mixed Reality (MR) can be characterised by the integration of virtual and real objects, real-time interaction and 3D registration.

In addition to the inclusion of some virtual objects within the real environments, augmented reality makes it possible to remove or hide some objects. This is known as Diminished Reality.

Virtual Heritage in AR is a realistic interactive virtual historical building showcased in real environments. The virtual building can be placed in the same place as the original building or in any other site. Visitors can observe the virtual building and its shadows, and the interaction of sky illumination with the virtual building, with respect to the sun position at the specific location, date, and time, making it more realistic.

2. Motivation

Virtual Heritage is a new technology for preserving traditional cultures in modern civilization. Hakim et al. [10] introduced some of these motivations. Documenting historic buildings and objects regardless of any unexpected events, preparing educational history resources, reconstructing ruined historic monuments, visualizing scenes from viewpoints impossible in the real world due to size or accessibility issues, interacting with objects without risk of damage, and providing cheap virtual tourism and virtual museum exhibits.

In general, the main goal of this study is to give users the ability to visit a reconstructed, previously ruined, traditional building or object with no damaged parts. Eliminating travel expenses is the other reason for focusing on virtual heritage. An AR-based heritage technology offers visitors a taste of novelties from the past and the opportunity to experience a specific time or place, long forgotten.

Visiting many different historical places in one single real location is also another advantage of this project. Observing enormous buildings in a small place, such as a classroom, can be considered another benefit of this project. Finally, this paper is provided to highlight the principle improvement of generating realistic virtual heritage in real environments.

3. Related work

There are many works being done in virtual reality heritage, which are not using AR systems, such as Virtual Hagia Sophia [26], Virtual Campeche [27], The Virtual Pompeii project [28], 3D reconstruction [29,30], Xanthi city [23], Ancient Malacca Project [31], Iberian Art Museum [4] and Virtual exhibition [32]. These kind of virtual heritage projects however are not as effective as virtual heritage in augmented reality due to a lack of interactivity.

Augmented reality, or even augmented virtuality, enhances the realism and attracts visitors to the heritage building. Interaction between real environments and virtual buildings is the main reason to focus on virtual heritage in augmented reality systems.

Kolivand and Sunar [33] focused on creating realistic virtual objects in augmented reality. In these studies, the researchers worked on sky colour and semi-soft shadows with respect to the position of the sun, considering different locations, dates, and times. The final results were validated by comparing the similarities and differences of produced images and real environments. The highlighted parts in real and virtual environments were also compared to show the features of the technique and validate it. Similar to the techniques used by Xing et al. [34,35] and Liu et al. [36,37], they compared the results with the colour of real sky and the effect of the sky colour on real objects.

Papagiannakis et al. [38] is one of the oldest works, which presents augmented virtual humans in real environments in the case of off-line rendering. In this project, virtual humans, animals and plants are augmented in a real scenario of ancient Pompeii. The virtual humans are supported with face expression, speech and clothes which are simulated in real time. In 2005, and 2006 they extended their work to an innovative revival of life in ancient fresco painting [39,40]. Lack of realism and interaction between real and virtual objects is the main issue in this project.

ARCHEOGUIDE [41,42] is a project which reconstructs Ancient Olympic Games in Greece. In this project, visitors are able to choose one of the predefined tours to guide the visitor through the site.

Mourkoussis et al. [43] worked on projects called ARICH (Augmented Reality in Cultural Heritage) and ARCO (Augmented Representation of Cultural Objects) which focused on indoor rendering of virtual heritage. In these projects, virtual museums are constructed to cover the limitation of real museums e.g. reconstructing dishes, planes and tools.

Ruiz et al. [44] present a virtual heritage of archaeological Maya Cities for reconstructing Calakmul's archaeological site in augmented reality. This project aims to construct the virtual Calakmul and to reduce the cost of traveling through a deep tropical jungle for almost 5 hours. There are no shadows or realistic effects in this project.

Fritz, et al. [45] cooperated with a tourism application and presented an AR virtual heritage called PRISMA, known as the tourist binoculars. Using this integration, users can observe interactive multimodal information about a traditional building. The mounted binocular camera captured the data, which is sent to the processing unit resulting in an augmented stream, and included graphical data.

Valtolina [46] prepared a platform to integrate real and virtual environments to immerse users into a virtual environment, creating the illusion of being a real scene. In this platform, the user must be placed in front of a large apparatus with a pair of stereo glasses to make it feel like they are being placed in a virtual environment.

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