EVALUATION OF USER ACCEPTANCE IN AN AUGMENTED REALITY APPLICATION FOR ARCHITECTURAL VIRTUAL HERITAGE EXPERIENCE

BY

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ABSTRACT

Augmented Reality (AR) applications have seldom been developed for viewing and experiencing architectural heritage. Architecture is typically experienced and learned through tours of actual sites. This thesis proposes a new application based on augmented reality technology for users to experience learning and to enjoy architectural heritage. This thesis develops and evaluates AR in order to offer new and enjoyable experience to the public in which the users are able to use and play with a 3D representation of a Malay house. This thesis aims to evaluate user acceptance in an AR application for the architectural virtual heritage experience. This thesis has three objectives; to develop and document a process of developing a specific application, to evaluate the application in the field and the significance of its realism, and finally to discuss the findings and future potential development of the application. The case study, Rumah Pak Ali, was selected because it was recently damaged during a fire on its original site. Besides evaluating the response and feedback of users on this new technology, this study attempts to evaluate architectural heritage realism in an augmented reality application. This study employs the Design Science Research Methodology which emphasizes the need for constructive research methods that allow the disciplined, rigorous, and transparent building of the AR application as outcomes and to distinguish the work from and ordinary practice of development and application. This thesis will provide a high-quality, simple approach to AR evaluation, with more 'realism' for guidance and hence authentic experience and knowledge, to the users in exploring the architectural heritage content. This thesis will also facilitate and expedite the construction process for simulation as well as the 3D AR development for the architectural heritage components in AR. It is anticipated that this study will contribute a conceptual model of an architectural heritage realism and provide substantial empirical evidence for the level of realism that the AR application may offer to the architectural heritage community and give a better experience to the user in learning the architectural heritage. Finally, this thesis will demonstrate that realism elements play a significant role in the 3D AR application for public users.

Keywords: Augmented Reality, 3D, AR, Realism, Non-realism, architectural heritage

خلاصة البحث

نادِراً ما يَتِمُّ تَطوير تَطْبيق الوَاقِع المعَزَّز الـــ"إيه آر" لِعَرض وتجربة التُّراث المِعْماري. عادة يتِمّ تعلُّم وتجربة الهَنْدسَة المِعمارية من خلال جَولات للمَواقع الحقيقية والفِعليَّة ذاتها. تَقْتَرِح هذه الأُطْروحَة تَطبيق جَديد للمستخدمين يقوم على تِقَنيّة الواقع المعزز من اجل إِعْطائِهم الفُرصة للتَّجربَة والتّعلّم والاسْتِمتاع بالتّراثْ المعماري. وتعمل هذه الأطروحة على تَطْوير وتَقييم تطبيق الـــ"إيه آر" من أجل تَقديم تَجربة جَديدة ومُمْتِعة للجُمْهور، بحيث يكون المستخدم قادراً على استخدام التطبيق بِتِكْنولوجيا *الأبعاد الثُّلاثّيّة* لوَاحدٍ من المـــنازِل الملايَويّة. كما تَهْدِف هذه الأطروحة إلى تقييم قُبول المسْتَخْدم في تطبيق الـــ"إيه آر" للتجربة الافْتِراضيّة للتراث المعماري. ولهذه الأطروحة 3 أهداف: لتطوير وتَوثيق عمليّة تطوير تطبيق مُعَيِّن، لتقييم التطبيق في المِيدان ومَدى أهَميّته ودَلالتُه الواقعيّة، وأخيرا لمناقشة النتائج والتّنمية المسْتقبليّة المحتملة من التطبيق. هذا ولقد تمَّ اختيار لبَيْتِ العَمّ علي كنَمُوذَج دِراسَة حَالة، لأنه كان قد تَضرّر مُؤخَّراً من جرَّاء حريق نَشَب في البيت. وإلى جانب تقييم الاسْتِجَابة ورُدُودِ الفِعْل من قِبَل المستخدمين لهذه التكنولوجيا الجديدة، تحاول هذه الأطروحة كذلك تقييم واقعيّة التُّراث المعماري من خلال تطبيق الواقع المعزز. أيضا، تستخدم هذه الأطروحة **تَصْمِيم عِلم مَناهِج البَحْث العِلْميّ** والذي بدوره يُؤكّد على الحاجة إلى أسَاليب البحث البَنَّاءة التي تَسمح ببناء مُنضَبِط وصَارم وشَفَّاف لتطبيق الـــ"إيه آر" وتُميِّزه كنَاتِج مُختلف عن أعمال التّطوير والتّطبيق الاعْتِيَاديّة. وستوفّر هذه الأطروحة نَهْج عَالي الجَوْدَة وبَسيط لتقييم الـــ"إيه آر" مع المزيد من "الواقعيّة" وبالتّالي توفير تَجرُبة ومَعرِفة حقيقيّة للمستخدمين في اسْتِكْشاف مُحتوى التراث المعماري. كما سَتعْمل هذه الأطروحة على تسهيل وتَسْريع مُحاكاة عمليّة البناء فضلا عن تطوير الـــ"إيه آر" ذو الأبعاد الثلاثية لمكوِّنات التراث المعماري في الـــ"إيه آر". ومن المتوقع أن تساهم هذه الدراسة بتقديم نَموذَج مَفاهِيمي لواقعية التراث المعماري، وتقديم أدلّة تجريبية على مستوى عالٍ من الواقعية بما قد يُقدِّمُه تطبيق الـــ"إيه آر" لمجتمع التراث المعماري، وإعطاء تجربة أفضل للمستخدم في تعلم التراث المعماري. أخيرا، ستُثبِت هذه الأطروحة أن العناصر الواقعيّة تَلعب دَوراً هامّا للمستخدمين من خلال تطبيق الـــ"إيه آر" ذو الأبعاد الثلاثية.

كلمات البحث: الواقع المعزز، الأبعاد الثلاثية، إيه آر، الواقعية، غير الواقعية، التراث المعماري.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science in Built Environment.

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DECLARATION

I hereby declare that this thesis is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

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LIST OF ABBREVIATIONS AND TERMS

2D	2 Dimension
3D	3 Dimension
AR	Augmented Reality
CAD	Computer Aided Design
FBX	Filmbox
ICOMOS	International Council on Monuments and Sites
MR	Mixed Reality
MVR	Mixed Virtual Reality
NPR	Non-Photorealistic Rendering
UNESCO	United Nations Educational, Scientific, and Cultural Organization
VR	Virtual Reality

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Over the last several years, there has been a remarkable increase in the development and use of digital techniques and technology for the documentation, communication, and dissemination of knowledge of architectural heritage in general, and architectural and monumental heritage in particular. It cannot be denied that digital techniques and methods such as laser scanning, use of photogrammetry and CAD tools have gradually taken over the field of archaeology and heritage management. However, the diffusion of knowledge and information on heritage, which includes the education of the public through digital technology, remains one of the key challenges in the area of heritage preservation.

While the future will certainly see a steep rise in the use of documentation and survey of historical artefacts and monuments as three dimensional digital representations, challenges to be met include fulfilling the potentials of technologies such as virtual reality and augmented reality in diffusing and disseminating knowledge, which may result in the creation of a heightened awareness of heritage to the general public. Fulfilling this potential means creating ‘user-friendly’ and easily accessible technologies for the general public, encompassing the creation of interest, learning, and excitement through their interactive nature and capabilities.

1.1.1 Augmented Reality

Augmented Reality (AR) has changed the way people interact with technology, offering new ways for the communication of information. This includes the visualization of processes and the expression and communication of creative ideas. It represents a form of technology which has evolved from the initial development of Virtual Reality techniques, enabling the combination of both the virtual objects and real world information. It has been lauded as having great potential to assist the public in everyday activities (Azuma, 2001).

AR is different from Virtual Reality (VR) in one critical aspect, namely the preservation of the physical world as an object in which virtual objects are presented and interacted with. Fully immersive VR abstracts from the physical world in order to place the user in a completely computer-generated universe (Hoffman, 2012).

AR has been described as a "process of superimposing text, 2D pictures or 3D virtual objects onto live camera-images, in context of where the user is and which direction he or she faces" (Hoffman, 2012). AR further refers to the enhancement and augmentation of the physical world with electronically synthesized data (Milgram, 1994) with any display that can be observed by users to directly see through the view of the real world along with generated graphics that are superimposed (Hoffman, 2012).

In current development, applications and testing of AR technologies have included its use in the design and management of buildings, landscape, human anatomy, sculptures, heritage reconstructions, and teaching of science for topics including solar systems. In the engineering fields, AR is now tested as a tool to teach, demonstrate, and visualise abstract 3D concepts such as magnetic fields, turbulent flow structures, molecular models, mathematical systems, auditorium acoustics,

population densities, and information flows. These virtual experiences may be animated, interactive, or shared. They can integrate behaviour and functionality (Macintyre, Bolter, & Gandy, 2004). Today, AR technology is growing faster than any other virtual technology and has improved significantly over the past 20 years.

The potential and bright future of AR may be seen from the technology tested and developed by companies such as Google and Microsoft (Zackland, 2009) to the public. Google Glass is one such technology developed by Google and is now being made accessible to the general public. It consists of a transparent head-up display which is able to project visuals onto the real environment seen through the glass. Google Glass is one of the examples of Head-Attached Displays as described in Chapter 2 and is already available in the market today. AR has evolved from embedding static 2D images to video and 3D animation. The AR marker has also been developed with more advanced tracking technology from bar code tracking to image tracking, object tracking and environment tracking. The visuals of AR have also improved significantly as the contents become more realistic and detailed (Arpasolutions, 2012). These developments have led to high hopes for the AR industry in the future (Mccall & Braun, 2008).

1.1.2 Augmented Reality and Digital Heritage

It cannot be denied there is currently a resurgent interest in the development and expansion of the multidimensionality digital media in efforts to document, manage and diffuse architectural heritage. Scholars and practitioners in architecture, planning, archaeology, and related fields, as well as administrators of museums, galleries and archives, are now on the path of developing more and more digital capabilities and conversions of the present wealth of information in architectural heritage. The

growing popularity of platforms and tools due to their interactive nature is evident, such as the rising phenomenon of virtual museums and web-based historical encyclopaedias.

1.1.3 Architectural heritage

There has been an increasing development and usage of VR and AR in the reconstruction and dissemination of information on architectural heritage. Architectural heritage refers to the artefact and monuments that form the local heritage of the site.

Cultural Heritage, by virtue of its experiential nature and the importance of visualization, is one of the prime disciplines where AR is having a significant effect. One of the key drivers of historical preservation has been increased education and awareness of the public on the priceless value of heritage artefacts and monuments. As digital representations become more common today, future developments will witness the virtual and augmented reality technologies become more user friendly and engaging for the public.

AR, due to its mix of the ‘real’ and the ‘virtual’ environment, makes it possible to visualize heritage buildings on the heritage site itself. It is possible now to reconstruct a monument on an actual site and interact with the model or the information, making possible studies of such issues as historical function, construction, technology, and performance.

Hence, Owen (2005) demonstrated that archaeological or historical parks or museums represent an extremely significant potential and a meaningful area within which AR applications can be further applied. The AR content can be developed not only for historical specialists or people previously interested in historical heritage, but

may also be easily used and appreciated by non-specialists or first time visitors who may experience difficulties in imagining how a heritage site or monument had initially appeared.

1.1.4 VR, AR Technologies and the Issues of Realism

Computer graphics have long been linked to the quest to achieving realism. The quality of 3D graphics have always been linked to the field of reconstruction that is reconstructing in digital form of a ruin, an artefact, a building or a monument with the aid of technology. The extent of faithfully (re)creating environments, buildings, objects, for publics, scholars and professionals and end-users, are evidently important for cultural heritage communication.

Virtual Reality (VR) in particular has been seen by many researchers such as Bioca & Levy (1995) as a way to make museums, archaeological sites, heritage objects, visible and interactive. From a graphical point of view, researchers and the general public tend to expect these artefacts, and environments to be reconstructed as detailed (i.e. corresponding to the real environment) as possible, and also to have a degree of authenticity. If VR is an immersive 3D environment, into which users can enter and move around, the issue of realism is hence considered a fundamental requirement; where the physical attributes and behaviours of the real world are reproduced.

In AR, the degree of realism is linked to the aim of seamless blending of the ‘real’ and the ‘virtual’ worlds, becoming the key factor to an increased immersive effect and improved user experience. The general public have come to expect a high level of realistic impressions in their minds and have preconceived ideas driven by the

high quality experiences and visualisation in films and the cinematic industry. Hence, realism is still considered a significant yardstick of successful representation.

However, observations of user experiences with these unrealistic environments have sometimes turned out to be unsatisfactory (or not as positive as expected). After a bit of exploration, the interest of the user wanes, no matter how carefully reconstructed the place is. This is because the experience cannot be compared to the real-world experience, and no meaningful goal is offered to trigger tangible interaction. The magic of the real experience is not there, engagement remains low, and the information conveyed is not rich enough.

Recently, there has been widespread research in the UK and US into arguments for the lessening of photorealism in the world of virtual and augmented reality. These researchers argue that both the development of computer graphics techniques that enhance photorealism and the development of cultural representation are not necessarily correlated. There have been explorations of non-photorealistic rendering (NPR) techniques for archaeological and historical research and dissemination. The issue of the level of 'graphic' realism or the level of realistic interpretation or visualisation that is considered sufficient for the dissemination and diffusion of information remains debatable.

PhD candidate Juliana Abu Bakar (2012) applied VR to the cultural heritage of a Malaysian museum. She conducted a systematic user evaluation and analysis of user response, finding that users were not happy with the realistic rendering of the actual heritage site of red sand stone which was the actual colour and texture of the architecture itself. A large amount of time was spent achieving the realistic rendering of the model. A non-realistic model was used for model refinement development, and

it was found out that the non-realistic model was more or equally acceptable by the users.

Hence, this thesis not only focuses on the evaluation of an AR application for cultural heritage from a user's perspective but also an evaluation of user's responses to the degree of realism in representation. Since AR is an extremely novel technology in the context of Malaysia, an AR prototype development was created which included the reconstruction of a Malay heritage building that was destroyed by a fire. The process of the user's evaluation is carefully examined, before performing a more detailed evaluation on the user's response to a realistic versus a non-realistic version or counterpart of the same prototypical model.

Throughout the study, the contention and research question focuses on the significance of realism in the scenario of a 3D application used to view and experience and learn Malaysian architectural heritage. The aim was not only to assess the user's responses to AR in the field of cultural heritage preservation and dissemination, but to also evaluate their responses and perspectives on the degree of realism in its applications. A public museum setting was selected as the field of testing for the application and to further study the relative impact of the elements of realism for real-time 3D AR applications. Due to the limited financial resources and logistical issues, the AR prototype must be downscaled for an internal use low cost AR application using marker based AR is used as it is easier to handle with a higher degree of accuracy.

1.2 PROBLEM STATEMENT

While VR has been implemented and tested in Malaysia through past applications and advanced research such as by Abu Bakar (2013), realism elements of AR in cultural

heritage are still totally new and have yet to be developed and tested. It is the aim of this thesis to evaluate the application of such technology in the field of cultural heritage with a focus on architectural heritage from the point of view of the users, and to also delve into a comparative study of the relative impact of realistic representation on user responses.

Recently, AR technology has been touted for not only, its capability to help visualize the past and building construction that is no longer in existence, but to also enable the use of digital interactive technology which is low cost and able to be economically implemented in both formal and informal educational settings and institutions in developing countries. One of the strongest points of using Augmented Reality for dissemination of heritage is that it is game-like, includes fun elements in learning, and may be realised by many devices (Namdaria, 2011).

Authenticity and accuracy are what historians and museum practitioners strive to achieve and what the general public come to expect. Yet to emphasize realism would run the risk of limiting the reality construction to creation of only historically accurate worlds and less time is utilized to develop the interactive capabilities of the application. Hence, this thesis focuses on the issue of realism, and whether such criteria or characteristics are significant in the context of AR applications intended for cultural heritage objectives.

This thesis deals with two issues; firstly the response of the user towards using augmented reality to disseminate and learn about architectural heritage; and secondly looking into the impact of realism based on an evaluation of user's responses to two counterpart models.

1.3 SCOPE OF STUDY

Due to the limited budget and constraints of the study, the scope of study is limited to the evaluation of an AR prototype application in an indoor setting in general, and within the confines of a museum in particular. It is beyond the scope of the study to develop and test AR outside in real external settings due to the lack of resources and infrastructure for such a test. The level of the Malaysian public in terms of their capabilities and resources must be taken into account.

Since Augmented Reality is a new technology in the Malaysian context in general and cultural heritage in particular, this thesis attempts to develop and evaluate an AR application for public use in the field of architectural heritage and then to evaluate such an application from a user's standpoint. Hence the AR application and evaluation will test the technology, utilizing familiar and affordable elements to the Malaysian public such as the iPad tablet.

The thesis focuses its investigation on the issue of realism which has been an issue in the visualization from a developer's viewpoint. A significant amount of resources are typically spent achieving this visualization aspect of AR application. The question is whether the focus on the effort on technologies and resources to enhance the realism of an AR application is necessary or would be more effective or successful if the application used with more abstract visual techniques, in this case the non-realistic approach.

Because this study is conducted in Malaysia, hence the focus on Malaysian traditional architecture is used as a case study. Recently there have been various concerns about the gradual disappearance of Malay architectural heritage including the traditional timber house structures of the Malay world. A recent fire had completely razed a significantly valuable and precious Malay architectural heritage