



**ARCHITECTURAL HERITAGE LEARNING
THROUGH VIRTUAL REALITY IN MUSEUMS**

BY

JULIANA AIDA ABU BAKAR

**Thesis submitted in fulfilment of the requirements for
the degree of Doctor of Philosophy**

**Kulliyyah of Architecture and Environmental Design
International Islamic University
Malaysia**

AUGUST 2012

ABSTRACT

Loss of world heritage sites due to massive earthquake, building erosion, human activity, natural disaster, et cetera has been central issues of cultural heritage sites preservation and documentation to safeguard these places of cultural importance for future generations. As such, many research and development projects using digital media, particularly using three-dimensional reconstruction, have been done to acquire and preserve the cultural information and architectural documentation of these heritage sites. However, little is found on disseminating these masterpieces using virtual reality technology for public knowledge and hence there is lacking of user evaluation being undertaken to gauge user responses in real-world use. The central aim of this thesis is to evaluate virtual reality for cultural heritage sites in real-world use. Thus, the objectives of this thesis are as follows: (i) to determine the user requirements of virtual reality for cultural heritage sites in real-world use, (ii) to design and develop a prototype of virtual reality application for cultural heritage sites, and (iii) to evaluate the effectiveness of the developed virtual reality application for cultural heritage sites in the context of Malaysian museums. This study adapts the Design Science Research Methodology, which emphasizes on the need for constructive research methods that allow the disciplined, rigorous and transparent building of a virtual reality application as outcomes and to distinguish the work from an ordinary practice of developing an application. According to user requirements gathered from expert interviews, a virtual reality prototype for architectural heritage was designed and developed. During the development stages, three expert reviews were conducted to inform the design. A functional virtual reality prototype was then evaluated by visitors in two museums and students in a laboratory setting. Data collection techniques include quasi-experiment, observation, and post-interview. Usability results were satisfactory for virtual reality, however, observation revealed visitors had difficulties in navigation using two input devices. Presence results were significant for field of view and sense of scale and factors contributing to presence were identified from user responses. For learnability, the user evaluation revealed that by using the virtual reality, visitors were able to capture architectural elements and social interaction that leads to meaning-making in museums has taken place. Comparisons between virtual reality and video and the Web were also discussed. User responses suggest that VR was preferred mainly due to its self-control navigational capabilities and its visual realism which both giving them sense of presence in that cultural heritage site. The thesis provides an empirical evidence of virtual reality in architectural heritage learning in terms of usability, presence, and learnability. Besides, this thesis has proven that virtual reality can technically preserve the architectural elements of a cultural heritage site. This thesis also provides lists of user requirements from perspectives of experts and the general public to assist future virtual reality for architectural heritage learning development projects.

خلاصة البحث

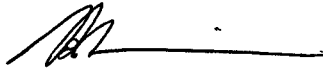
كان ضياع معالم التراث العالمي بسبب الزلزال الهائل ، والانهيار الأرضي ، والنشاط البشري ، والكوارث الطبيعية ، وغيرها . وأصبحت هذه الظاهرة إحدى القضايا المركزية ذات علاقة بحماية وتوثيق معالم التراث الثقافي ، وذلك لأجل حفاظ هذه الأماكن ذات الأهمية الثقافية للأجيال القادمة . والعديد من مشاريع الدراسة والتنمية عادةً تكون باستخدام وسائل الإعلام الرقمية ، وبخاصة باستخدام ثلاثي الأبعاد في إعادة تشكيلها . وقد تم استخدامها للحصول على المعلومات الثقافية والتوثيق المعماري لهذه المعالم التراثية . ومع ذلك ، تم العثور على نشر هذه التحف نادراً باستخدام التقنية الواقعية المظهرية لمعرفة العامة . وبالتالي ، هناك النقص والخلل من المستخدم في تقييم الردود الفعلية في العالم الاستخدام الحقيقي . والهدف الرئيسي هذه الرسالة هو تقييم عالم الواقع الافتراضي لمعلم التراث الثقافي في العالم الاستخدام الحقيقي . وأما الأهداف العامة هذه الرسالة ، فهي كما يلي : i. تحديد متطلبات المستخدم من عالم الواقع الافتراضي للمعلم التراثية الثقافية في العالم الاستخدام الحقيقي . ii. تصميم وتطوير النموذج الأولي من عالم الواقع الافتراضي لمعلم التراث الثقافي . iii. تقييم فعالية تطبيق الواقع الافتراضي لمعلم التراث الثقافي من البلدان المتقدمة في سياق المتاحف في ماليزيا . وهذه الدراسة تطبق منهجية التصميم في الدراسة العلمية ، والذي يؤكد على حاجتها الماسة إلى مناهج البحث البناء التي تسمح في تطبيق الواقع الافتراضي المنضبط والشفاف والصارم ، وبالتالي تكون النتيجة جيدة من ممارسة النشاط العادي للتطوير والتطبيق . وبالنظر إلى متطلبات المستخدم ، تم جمعها من مقابلات الخبراء . والوقت ذاته ، وقد تم تصميم النموذج الأولي للواقع الافتراضي للمعماري وتطويره . وفي أثناء مراحل التطوير ، وقد تم استعراضه على الثلاث الخبراء بغية تعريف هذا النموذج إياهم . ومع ذلك ، كان هذا النموذج الأولي للواقع الافتراضي قد تم تقييمه من قبل الزوّار في المتحفين ، وأيضاً من قبل الطلاب في مكان مختبر . كما تم جمع البيانات من خلال الوسائل العديدة منها شبه التجربة ، والملاحظة ، والمقابلة البعدية . وكانت النتائج المستخلصة من ذلك مقبولة للواقع الافتراضي . وعلى الرغم ذلك ، كشفت مراقبة الزوّار على صعوبة التنقل باستخدام أجهزة ثنائية مساهمة . وكانت هذه النتائج مهمة من ناحية وجهة النظر ، والشعور ، والعوامل الأخرى التي تتعارف من خلال الردود الفعلية من المستخدم . ومن ناحية قابليته على الدراسة ، كشف التقييم على أن باستخدام الواقع الحقيقي ، يستطيع الزوّار على التقاط العناصر المعمارية والتفاعل الاجتماعي الذي يؤدي إلى كشف الأسرار والمعاني في المتاحف . كما تم المناقشة حول المقارنة بين الواقع الافتراضي ، والفيديو ، والشبكات الإنترنت . وردود فعلية المستخدم تشير إلى أن أولوية استخدام الواقع الافتراضي تتوقف على قدرة ذاتية في ضبط التنقل وفي واقعه الافتراضي الذي تعطيه الإحساس الحقيقي لمعلم التراث الثقافي . وإضافة إلى ذلك ، أن هذه الرسالة تقدم دليلاً عملياً للواقع الافتراضي في مجال دراسة التراث المعماري من حيث قابليته للاستخدام ، والمشاركة ، والدراسة . ومع ذلك ، أثبتت هذه الدراسة على إمكانية الواقع الافتراضي في الحفاظ على العناصر المعمارية من ناحية الفنية للمعلم التراث الثقافي . كما أن هذه الرسالة تقدّم قوائم متطلبات المستخدم من وجهات نظر الخبراء والعامة للمساهمة في تطوير الدراسة والمشاريع حول الواقع الافتراضي للتراث العمراني في المستقبل .

ABSTRAK

Kehilangan tapak warisan dunia akibat gempa bumi, hakisan bangunan, kegiatan manusia, bencana alam dan seumpamanya menjadi isu utama dalam pendokumentasian dan pemeliharaan tapak warisan budaya dalam usaha melindungi tempat-tempat kebudayaan yang penting kepada generasi masa hadapan. Untuk itu, projek-projek penyelidikan dan pembangunan menggunakan digital media, terutamanya pembangunan semula tiga dimensi, dilaksanakan untuk memperoleh dan memelihara dokumen senibina dan maklumat budaya tapak warisan ini. Walau bagaimanapun, amat sedikit karya-karya ini disebar dengan menggunakan teknologi realiti maya dan mengakibatkan kurangnya penilaian pengguna sebenar dijalankan ke atas teknologi ini. Matlamat utama tesis ini adalah untuk menilai realiti maya untuk tapak warisan budaya dalam penggunaan dunia sebenar. Dengan itu, objektif-objektif tesis ini adalah: (i) untuk menentukan keperluan pengguna realiti maya tapak warisan budaya dalam penggunaan dunia sebenar, (ii) untuk merekabentuk dan membangunkan satu prototaip aplikasi realiti maya tapak warisan budaya, dan (iii) untuk menilai keberkesanan aplikasi realiti maya tapak warisan budaya dalam konteks muzium di Malaysia. Kaedah kajian ini mengadaptasi Kaedah Penyelidikan Sains Rekabentuk, yang menekankan keperluan kaedah penyelidikan ke arah penghasilan aplikasi realiti maya yang telus, ketat dan berdisiplin, serta membezakan kajian ini daripada amalan biasa pembangunan aplikasi. Prototaip realiti maya untuk warisan senibina telah direka dan dibangunkan mengikut keperluan pengguna yang dikumpul dari temubual pakar. Pada peringkat pembangunan, ulasan pakar telah dijalankan untuk menetapkan rekabentuk. Satu prototaip realiti maya berfungsi kemudian dinilai oleh pelawat-pelawat dalam muzium dan pelajar dalam persekitaran makmal. Teknik pengumpulan data termasuklah quasi-eksperimen, pemerhatian, dan temubual. Keputusan kebolegunaan bagi realiti maya adalah memuaskan, walau bagaimanapun, pemerhatian mendapati pelawat mempunyai kesukaran dalam navigasi menggunakan dua peranti input. Keputusan kehadiran adalah signifikan dari segi bidang pandangan dan rasa skala, serta faktor-faktor yang menyumbang kepada kehadiran telah dikenal pasti daripada maklumbalas pengguna. Untuk kebolebelajaran dengan menggunakan realiti maya, pengunjung dapat menguasai unsur-unsur senibina dan mewujudkan interaksi sosial dalam penghasilan makna di muzium. Perbandingan antara realiti maya dan video serta Web turut dibincangkan. Pengguna menyatakan VR digemari kerana keupayaan kawalan pelayaran sendiri dan visual, di mana kedua-duanya memberi mereka rasa kehadiran di tapak warisan budaya. Tesis ini menyediakan bukti empirik realiti maya dalam warisan senibina pembelajaran dari segi kebolegunaan, kehadiran dan kebolebelajaran. Di samping itu, tesis ini telah membuktikan bahawa, secara teknikal, realiti maya dapat mengekalkan unsur-unsur senibina tapak warisan budaya. Tesis ini juga menyediakan senarai keperluan pengguna daripada perspektif pakar dan orang awam untuk membantu pembangunan projek realiti maya dalam pembelajaran warisan senibina kelak.

APPROVAL PAGE

The thesis of Juliana Aida Abu Bakar has been approved by the following:



Puteri Shireen Jahn Kassim
Supervisor



Murni Mahmud
Co-Supervisor



Zuraini Denan
Internal Examiner

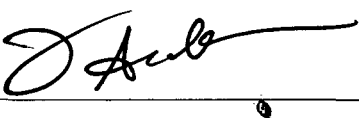
Nor Laila Md Noor
External Examiner

Radwan Jamal
Chairman

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.

Juliana Aida Abu Bakar

Signature:  _____

Date: 15/8/2012

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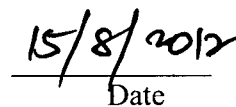
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ACKNOWLEDGEMENTS

In the name of Allah, the Most Gracious and the Most Merciful

I would like to express my heartfelt gratitude to those who have been crucial in the completion of this thesis. Firstly, I am grateful to be working under the supervision of Assistant Prof. Dr. Puteri Shireen Jahn Kassim who provided a constant support and guidance in grounding the conceptual and development framework at the beginning of this research and shared her deep thoughts on the flow of this thesis. Many thanks to co-supervisor, Assistant Prof. Dr. Murni Mahmud who was willing to share the technical bits of experimental design procedure and putting advices from human-computer interaction perspective. Working under the supervision of both has made my journey valuable as they were always there when I was in dire need of advices by sharing their thoughts and experiences in almost anything.

I would like to extend my gratitude to the following authorities for their goodwill and support during the preliminary study:

- Mr. Ibrahim Ismail, Director, Department of Museums Malaysia;
- Madam Mahani Muhammad, Manager, Corporate Communication, Department of Museums Malaysia;
- Mr. Engku Md Azmi Engku Abdul Rahman, General Manager, Taman Tamadun Islam;
- Mr. Kamarul Bahrin A. Kassim, Director, Muzium Negara;
- Madam Janet Tee, Deputy Director, Muzium Negara;
- Mr. Hj Khamis bin Abas, General Manager, Malacca Museums Corporation;
- Mr. Mohd Azmi Mohd Yusof, Director, Architectural Museum Malaysia.

Heartfelt thanks to these museum personnel for their courteousness as well as for spending their precious time and effort in making interview sessions a success:

- Madam Asmah Mohd Wazir, Principal Assistant Director, IT Division, Department of Museums Malaysia;
- Mr. Mohd Fadzir Sulaiman, IT Administrator, Islamic Arts Museum Malaysia;
- Madam Raja Zainuraini Raja Ali, Assistant Curator, Sultan Azlan Shah Gallery;
- Mr. Fauzi Oslaini Othman, Assistant IT Officer, Pahang Museum;
- Mr. Zakaria Bujang, Assistant Chief Information Officer, Department of Sarawak Museums;
- Assistant Superintendent Police Ab. Rashid Hj Mohamad, Assistant Curator, Royal Police Museum;

- Mr. Azlan Hafiz Mukhti, Curator, Kota Tinggi Museum;
- Mr. Hasnul Jamal Saidon, Director, Museum and Gallery Tuanku Fauziah;
- Madam Nor Laila Abd Rozak@Razak, Curator, Museum and Gallery Tuanku Fauziah;
- Mr. Hamidun Bakar, Operations Manager, Museum of Telecommunication;
- Mr. Mohamad Firdaus Nosri, Assistant IT Officer, State Museum;
- Mr. Afzal Affendy Ab. Razak, Assistant IT Officer, Malacca Museums Corporation;
- Mr. Amran Yusri Ahmad Shah, Assistant Administration Officer, Kedah State Museums Board;
- Mr. Ismail Mansor, Curator, Department of Sabah Museums;
- Mr. Arif Abd Hamid, Curator, Department of Sabah Museums; and
- Mr. Fairudz Ikhwan Zulkifli, Assistant Curator, Penang State Museum and Art Gallery.

I presumed that the prototype development section was hard without the help of many young and talented people:

- Syed Huzaifah Syed Omar for his VR programming skills,
- Mustaffa Kamal Bashah Abdul Bashir who stayed overnights to render and make 3D simulations,
- Zainal for his final touch on video and multimedia contents,
- Husam Abdulfatah Haron for his expert advice on 3D modelling,
- Edry Faizal Eddy Yusof for his early contributions on multimedia and animation contents, and
- Irfan Hassan, Mohd Fadhli Ilias, Muhammad Afiq Ibrahim Shukri, Mohammad Nazirulhaq Abdul Wahab, and Abdul Fattah Abd Ghani - the 3D modelling team who sacrificed their semester break to be indulged in this development project.

I wish you all prosperous years ahead and may your skills and talents flourish.

Series of user evaluation conducted during this study would never succeed without the help and commitment from the participating museums. I extremely appreciate the contribution of Hasnul Jamal Saidon, the director of Museum and Gallery of Tuanku Fauziah, University Science Malaysia (MGTF), who during our stay there has shared us the joy of the good news of being promoted to Associate Professor, because of his willingness to lend a space at his premise as well as handful resources and personnel for this study to reach its intended audience, and even shared some of his thoughts in museum industry and academic research though he had tight schedules; and Norlaila

Abd Razak, our MGTF liaison officer, for her patience and hospitality in making our nine-day stay at MGTF a comfortable one.

My utmost appreciation also goes to Mr. Haji Khamis Haji Abas, General Manager of Malacca Museums Corporation for his permission to conduct the second phase of evaluation at his premise in the midst of peak season where at that point of time Malacca, the Land of Historical City hosted Sukan Malaysia SUKMA 2010 and almost all his staffs involved in organizing River Carnival and Food Festival 2010, a blessing indeed for this study in terms of drawing visitor's participation; Madam Nor Azimah Md Ali (curator at Malacca Sultanate Palace) and Mr. Mohd Shukry Abdullah (curator at Qur'an Museum) who helped determining the suitable port for the prototype; and Mr. Ahmad Sabri Epit (staff at Malacca Sultanate Palace) for his companion throughout our nine-day stay at Malacca Sultanate Palace.

For financial contribution, my sincere thanks to Universiti Utara Malaysia and Ministry of Higher Education for granting me the scholarship under Public Higher Education Academic Training Scheme. I would like to extend my gratitude to Multimedia Development Corporation, Malaysia (MDeC) for generously contributing a substantial amount of financial assistance for the prototype development and allowing access for the development team members to use its virtual reality center (VRC) and multimedia facilities. I would also like to thank Ministry of Higher Education for funding the evaluation part of this thesis through its Fundamental Research Grant Scheme (FRGS) and IIUM for its substantial funding on the preliminary work of this thesis. I appreciate the contribution of KAED IIUM Heritage Studies and the KAED Library of Yayasan AlBukhari Chair Holder for supplying the development team with plenty of primary and secondary resources in order to complete this project. Most heritage pictures, valuable texts, and 2D drawings were taken from their resources.

The journey was indeed very lonely and I did very much treasure the companionship of my beloved family at all times during my ups and downs: my loving husband Mohd Hasbullah Omar who was also struggling in the same journey, my vibrant heroes Ahmad Fathi and Ammar Haseef, and glowing princesses Fatimah Azzahraa and Haidatul Alimah. Not forgetting the support and Du'a from my parents, Abu Bakar Yeop and Junaidah Nordin, and my parents-in-laws, the late Omar Haji Din and Zubaidah Haji Shafiei who persistently instilled the importance of balancing career and family in life. I did appreciate the helping hands of Fatin Liyana and Nurul Hana who were always there to entertain my kids during the times I was not possible to entertain them.

For those names who did not appear, I thank you all for directly or indirectly contributing to the completion of this thesis.

Last but not least, this journey would not be possible without God's willing. Therefore, I thank Allah the Almighty for granting me good health, good mind, patience, guidance, and courage to endure this journey and to persevere all unforeseen circumstances throughout, *Alhamdulillah*, all praises to Allah.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

There has been a steady increase in identifying the potentials of and providing empirical evidence of virtual reality (VR) for learning. Beginning with Youngblut (1998) who explored the educational potentials of VR for learning by reporting more than 60 educational projects, recent studies provide statistical evidence that school students performed better in the VR learning environment provided that they actively participated in the learning process (Lee, Wong, & Fung, 2009; Chen, 2006). Apart from academic performance, VR has produced positive learning experiences for students such as enjoyment, sense of reality, ease of understanding, and satisfaction (Lee et al., 2009). In formal education, VR offers a handful unique experiences such as hands-on learning, group projects and discussions, virtual field trips, simulations, and concept visualization to both teachers and students together with successful instructional strategies (Inoue, 2007). A recent study by Harrington (2011b) suggests that the use of desktop VR with high visual realism and high navigational freedom have provided positive learning gain.

In informal education particularly in museums, there are diverse learning theories of informal learning and mental models that constituted learning in museum context such as the contextual model of learning (Falk & Dierking, 2000), the complex behavior of visitors (Pujol-Tost & Economou, 2006), and the significance of such studies to be embodied in overall museum experience (Pujol-Tost & Economou, 2008). In museum context, the historical interpretation, storytelling, contextualizing objects, allowing artistic means of expression, and creating emotional response to visitors are keys to successful museum visits (Roussou, 2004, Pujol-Tost & Economou, 2006). The concept of 'Cultural Presence' to denote a feeling of different people with diverse culture being

in a virtual place (Champion, 2006) has been argued to have impact towards learning cultural heritage whereby immersion, enjoyment, engagement, and interaction between visitors and exhibits were among the attributes (Pujol-Tost & Economou, 2009).

Information and communication technology (ICT) refers to the technology of acquiring, storing, processing, and disseminating information through the use of computer technology and telecommunications (Dewan Bahasa dan Pustaka, 2005). Recent advances in ICT have affected the way teaching and learning is delivered in both formal and informal education. For formal education, Malaysia is reaping the benefits of ICT through 'Smart School' project under MSC Malaysia initiatives. This project has integrated the use of ICT for teaching and learning into the school syllabus to subsequently reduce the digital divide among citizens.

Museums that safeguard and preserve the heritage of a nation should reap the benefits of ICT to help disseminate the knowledge to the general public. While studies on formal education are heavily focused on the impact of ICT and the Internet and how they may fit in subjects curriculum, the use of ICT in informal education such as in museums and other cultural institutions have been less studied. There, relatively more freedom to adopt ICT due to its flexibility of learning methods and styles. The ambient of non-structured curricula and self-dependent learning is more or less light compared to the formality of classrooms (Sefton-Green, 2004) although these institutions can also act as formal settings, for instance, during school excursions.

There are general guidelines for designing an interactive museum exhibit that emerged from previous studies such as it should be suitable for learning where it contains different linked elements with appealing contents; enjoyable and engaging; easy to use where it must be intuitive and has clear affordances so that visitors can concentrate on its content, and suitable for groups where it allows group exploration (Economou & Pujol-Tost, 2006, Pujol-Tost & Economou, 2008). These guidelines were derived from series of interview on user perceptions after using ICT exhibits which were already installed in those cultural heritage settings. In general, Economou & Pujol-Tost

(2006) and Pujol-Tost & Economou (2008) have concluded that the use of interactive ICT such as VR is capable of providing the rich elements of the learning experience to museum visitors.

1.1.1 Operational Definitions

The following are operational definitions of the major terminologies used in this thesis:

- i. Virtual Reality (VR) refers to a three-dimensional, computer-generated, and information-rich environment that provides spatial navigation, allows user control, and provides some degree of interaction between user and virtual objects (Brooks, 1999; Bowman et al., 2005; Shneiderman & Plaisant, 2010). Virtual reality applications dedicated for cultural heritage is called virtual heritage as per definition used in Champion (2006) and Bogdanovych et al. (2011). There is a wider definition of virtual heritage that includes anything digital and computer-generated or online as per definition of Addison (2000) and Gillam et al. (2010). The first definition of virtual heritage is used throughout this thesis unless otherwise stated.
- ii. Cultural Heritage (CH) Site is “a place, locality, natural landscape, settlement area, architectural complex, archeological site, or standing structure that is recognized and often legally protected as a place of historical and cultural significance” (International Council on Monuments and Sites [ICOMOS], 2008). Throughout this thesis whenever appropriate, the term ‘Architectural Heritage’ (ARCH) is interchangeably used with the term CH to specifically refer to the architectural significance of a cultural heritage site. The term is similarly used by ICOMOS in naming one of their scientific themes as The International Scientific Committee on Earthen *Architectural Heritage* (ISCEAH) which responsible in studying and conserving the structures and materials of Earthen Architecture (ISCEAH, 2008).