

# **Digitization of Museum and Art Gallery: A Framework for Enhancing User Interactivity and Personalization in On-site Environments.**

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Submitted in fulfilment of the requirements of the degree of  
Doctor of Philosophy

March 2015

# Abstract

Digital curation is an emerging topic of interest in the current museum development. If on-site museum experience can be enhanced by digital technology, the development of digital curation in cultural expression can not only promote the role of museum in this digital era but also boost the value of cultural heritage more than ever before. This research focuses on the development of digital curation in cultural expression applications, such as museums and art galleries, with special attention to the user experience perspective. The goal is to provide a novel approach that helps to enhance visitors' on-site museum experience through digital technology. We illustrate how the use of technology can improve the production process and increase the interaction and personalization between visitors and collections by evaluating a prototype that is developed based on this principle.

The prototype is developed under the Service Oriented Architecture, and consists of three different sections, an iOS UI mobile interface front-end written in Objective-c for visitors to interact with the collections during their visit; a web based inter-media platform built using PHP-MYSQL for data communication between the front-end and back-end; and a back-end collection recommendation database developed using Apache Jena - a free and open source Java framework which stores information of collections using semantic technology. This approach demonstrates a design of the UI interface for a series of Australian paintings in the National Gallery of Australia, and illustrates a framework showing how the visitors' behaviour can be detected by interacting with the designed interface, and thereby offering a feedback of recommendation for establishing a personalized visit trajectory.

# Statement of Originality

*This work has not previously been submitted for a degree or diploma in any university. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made in the thesis itself.*

(Signed)\_\_\_\_\_

Name of Student: Richard, Yu-Chang Li

# Acknowledgement

I would like to express my special appreciation and thanks to my supervisor Associate Professor Alan Wee-Chung Liew, you have been a tremendous mentor for me. I would like to thank you for encouraging my research and for allowing me to grow as a research scientist. Your advice on both research as well as on my career have been priceless. I would also like to thank my co-supervisor, Dr. Jun Zhou, for serving as my advisor even at hardship. I also want to thank you for your brilliant comments and suggestions of my thesis at the last moment, thanks to you. I am also indebted to the students who volunteered to participate in this project. Many thanks for completing the research prototype and the study questionnaires. All of you have been there to support me when I recruited participants and collected data for my Ph.D. thesis. I would especially like to thank Kimmim Sinha and my colleagues Ail Zia, Alessandro Marani, Diletta Luna, Fawad Riasat RAJA, , Krist Komkrit, Umberto Baresi, and all of my friends around the world (too many to list here but you know who you are!). Thanks a lot guys for sharing my happiness and sadness throughout this journey.

A special thanks to my family. Words cannot express how grateful I am to my mother and father for all of the sacrifices that you've made on my behalf. Your prayer for me was what sustained me thus far. I would also like to thank all of my friends who supported me in writing, and incited me to strive towards my research. Overall, I would not forget to thank the staff and faculty members of Griffith University who helped me either directly or indirectly to achieve my goal.

*I dedicate this thesis to  
my family for their constant support and unconditional love.  
I love you all dearly.*

# Dissemination of Study Results

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2. Li, R.Y.C, Liew, A.W.C, & Su, W.P, (2012).THE DIGITAL MUSEUM : CHALLENGES AND SOLUTION. IDCTA2012: 8th International Conference on Digital Content, Multimedia Technology and its Applications. Jeju, Korea.

## Book Chapters:

1. Li, R.Y.C, & Liew, A.W.C, (2014). The Challenges of Digital Museum. In M. Khosrow-Pour (Ed.), Encyclopedia of Information Science and Technology (Third., p. 4929-4937). USA: IGI Global. doi:10.4018/978-1-4666-5888-2

## Journal Articles:

1. Li, R. Y.-C., & Liew, A. W.-C. (2015). An interactive user interface prototype design for enhancing on-site museum and art gallery experience through digital technology. Museum Management and Curatorship, 1–22. doi:10.1080/09647775.2015.1042509
2. Li, R.Y.C, & Liew, A.W.C, Digital Era- A Crisis Turning Point of Digital Curation and Museum Observations. Curator-The Museum Journal. (Under review)

## Presentations:

1. Li, R.Y.C, Liew, A.W.C, (2013). The Challenges and Solution in the Preservation of Digital Heritages. MediAsia 2013: Asian Conference on Media & Mass Communication. Osaka, Japan.
2. Li, R.Y.C (2012). The future of museum. Research Students Conference 2011. Griffith University. Brisbane, QLD, Australia.

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# 1.Introduction

## 1.1 Summary of research

From time immemorial, the way traditional museum exhibits have always been limited to leading the audience into showrooms to view the original collections. However, due to the limitations of factors such as exhibition space, venues, and schedules, the total number of direct contacts with exhibits is in the minority. For instance, the National Palace Museum (NPM) of Taiwan, which contains more than 650,000 domestic and foreign antiquities, has continuously increased its collections by purchasing or accepting donation of artefacts. The entire collection would take over 30 years to exhibit if each exposition was run for three months at a time (Chou, 2010). In this case, a museum would seem like an antiquity warehouse, which is unapproachable and distant. Moreover, since antiquities belong to all citizens, the traditional museum has a predicament where owners cannot freely access information about their properties. According to the statutes of International Council of Museum (ICOM) (2007):

A museum is a non-profit, permanent institution in the service of society and its development, open to the public, which acquires, conserves, researches, communicates and exhibits the tangible and intangible heritage of humanity and its environment for the purposes of education, study and enjoyment. (p.2)

This statement expresses a metaphor that an important role of a museum is to make its heritages become a part of people's life, much like the functions of a library. Based on this aspiration, the digital curation<sup>1</sup> of a museum has become a common pursue in both academic and public sectors.

Theoretically, cultural institutions should function as a learning environment (J.H. Falk & Dierking, 2000). However, according to Coulter-Smith (2006), the constitutions of social communication and art collections have been hampered by the operating patterns of galleries for a long time. People who visited museums or art galleries often do not understand the deeper meaning of the collections. Some questions that visitors often have about the exhibits are:

1. What is the background of the collection?
2. What is the background of the creator?
3. What is the creator's state of mind during the creation?
4. What is the collection trying to say?
5. Where is the collection which I am most interested in?

In 2012, Robert Stein, the deputy director of Indianapolis Museum of Art, indicated that the use of digital technology has improved the production process in conventional museums and art galleries and has greatly facilitated the interaction between visitors and collections(Stein, 2012). Although the concept of digital museum<sup>2</sup> has attracted a lot of attention in the past decade, there remain many

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<sup>1</sup> Digital curation is a framework of digital information processing and digital content generation involving steps such as digital imaging, object digitization and scanning, and digital visualization and display. The artefacts will be stored in a digital format with metadata description for further retrieval.

<sup>2</sup> Digital museum is a museum exhibition platform that utilizes computer and information technology, on which cultural relics and historical collections can be preserved and displayed in digital format. It is one of the main outcomes of digital curation.

challenges to be addressed such as digitization, preservation, and user experience.

This research focuses on the development of digital curation in cultural expression applications, such as museums and art galleries, with special attention to the user experience perspective. The goal is to provide a novel approach that helps to enhance visitors' on-site experience through digital technology. We illustrate how the use of technology can improve the production process and increase the interaction and personalization between visitors and collections by evaluating a prototype that is developed based on the asserted theory and framework. The field studies presented in this research, which are about the current progress in the practical development of digital museum from several major organizations, provide a research foundation to clarify what have been done in the current industries and what are the challenges that need to be solved in the future.

## 1.2 A problem statement

Although the museum digitization movement has been ongoing for over a decade since the beginning of the 21st century, the factors of visitor experience have largely been ignored in the development of digital museum due to low visibility of its impact and difficulty in quantifying its outcomes. The term “digital curation” first emerged in an academic seminar convened by the Digital Preservation Coalition and the British National Space Centre in London on 2001 to discuss the improvement of the Open Archival Information System Reference Model (OAIS) standard and the knowledge sharing of digital curation in various fields (Constantopoulos & Dallas, 2008). However, the huge advancement of information technology has turned the digitization process to become more progressive and diversified. Accordingly, virtual museum has become a platform where museum connects with their clients outside the museum building. Many well-known museums have committed to create their virtual environment by either putting the digitized information onto their web pages or presenting their pre-recorded tour guide through portable devices, such as the

Collection Database (Compass) of The British Museum (Loverance, 1998); the virtual museum of The Louvre on the iPhone (LeVitus, 2010); and The Metropolitan Museum of Art's Timeline of Art History (The Metropolitan Museum of Art, 2011). A common feature of these efforts is that the information can be received by the visitors quicker and easier without time and space limitation.

Although the development of museum seems to benefit from the application of digital technology, digitization of the museum has brought with it some disadvantages. For example, with the expansion of usage in virtual environment, the physical museum is becoming more isolated and functionless without visitors participation; meanwhile, the participants are also losing the opportunities for sharing and communicating their viewpoint with others. Thus, from the user's point of view, the digital museum is not to replace the traditional museum; rather, the digital information should complement the physical museum. Scott (2007) has found from her interview survey that the traditional value of museum has been unintentionally eroded in the process of museum digitization. She argued that the physical museum has an irreplaceable status in people's minds. Hence, the aim of museum digitization should be focused on healing the gaps of the physical museum rather than museum virtualization. As museum experience should be done by on-site appreciation with real objects, the enhancement of user experience in the physical museum, such as how to improve the interactive and personalized factors, will be the prime consideration in future museum digitization effort.

### **1.3 Technologically enhanced physical environments**

With the above concerns, this research is proceeded with the design of ubiquitous computing systems, which are incorporated within a physical space for achieving the factors that can be enhanced in virtual environment such as education, interaction and personalization. We expect that this approach could change the ways of perception and attitudes of visitors and boost the values and feelings provided by

physical collections when the system is deployed into an existing environment. In other word, our purpose is to reconnect the relationship between people and physical collection. Furthermore, we believe that it is also crucial for museum curators and system developers to analyse and understand these processes in order to design and evaluate the use of technologies in a thorough and effective way.

The approach that we proposed in this thesis is based on a prototype, which is developed in accordance with the theory and framework that we asserted in this research. If the prototype can be evaluated positively from the user feedbacks, the claimed theory and designed framework can prove their contribution. Thus, carefully developing a conceptual framework from the research questions and hypotheses turned out to be a vital task. We will discuss these points in the next section and outline the framework in detail in chapter 4 of this thesis.

## 1.4 Research questions and hypotheses

In order to focus on the user experience, the factors of interaction and personalization are the two major concerns. This research adopts several technologies to achieve these factors. For the enhancement of interaction, a platform of portable device for vital-data acquisition is chosen, which includes the technologies of Augmented Reality (AR) and Quick Response Code (QR Code). Therefore, in order to understand the current development of electronic devices in museum, the first and second research questions are asserted below:

- 1. Do existing museum electronic devices have enough capability to meet end-user requirements for interaction and personalization in comparison with the fast growth of other similar information technologies?*
- 2. Are there specific concepts and frameworks based on interaction with the physical environment that can contribute to the understanding of roles for visitors, curators, and collections?*



For the enhancement of personalization, the most well-known technology is the Semantic Web. This novel technology allows machine to better comprehend the information that is given by users. However, due to the immature ontologies and security issues, the development of Semantic Web in museum is still in its early stage. Hence, how to find a way to adopt a semantic based inference engine into museum setting for better understanding the visitor's behaviours is an important task in this research. For achieving this objective, the third and fourth research questions are:

3. *Is there any current inference engine available for the museum setting to make semantic recommendations?*
4. *If so, how to integrate semantic framework and portable platform for understanding visitor's behaviour?*

The above questions are investigated by a comprehensive literature review. Through extensive reading, it is noted that the features and motivation from the technologies of Semantic Web and AR could potentially enhance the user's on-site experience in the museum. The elements of interaction and personalization have been implemented separately using these technologies in different applications such as online shopping (Amazon, eBay), virtual map, as well as in archaeology through Virtual Showcase (Bimber, Encarnação, & Schmalstieg, 2003). However, none of these applications can be used to study the impact of these technologies in the museum setting as they are mainly targeted on the virtual environment only. For example, although Virtual Showcase can be deployed into a real environment to enhance the interaction, the lack of user feedback mechanism would obstruct the development of personalization.

Hence, how to combine and apply these technologies has become a major challenge. Based on the initial research questions above, the following hypotheses are generated:

1. *The factors of two-way interaction and personalization can be implemented by portable electronic devices.*

Once visitors can receive personalized recommendations during their interaction with the front-end devices, the museum electronic devices can enhance the on-site museum visiting.

2. *The combination of semantic inference and AR can be achieved in on-site museum exhibit.*

According to Tim Berners Lee, the goal of Semantic Web is to create machine readable content that allows information to be shared and reused across application and community boundaries for enhancing the usability and usefulness of the recourses (Breslin, Passant, & Decker, 2009). On the other hand, the application of AR can increase the interaction between users and exhibits within the museum setting (Wojciechowski, Walczak, White, & Cellary, 2004). Hence, if the combination of Semantic Web and AR can be achieved on-site, the visitor and curator's user experience can be improved.

3. *The value of cultural heritages can be increased by museum digitization.*

The digitized collections can be combined with different mediums outside the museum setting for further educational and commercial purpose. In this way, the value of cultural heritages can be expanded.

## 1.5 Structure of this thesis

This thesis consists of 10 chapters. After the introduction, chapter 2 presents a comprehensive review of relevant literature in the area of digital curation from the technical to user experience viewpoints. The discussion of technical aspect is

surrounded by the issues of data management and content storage in the digital museum and art gallery, particularly focusing on the long-term preservation. It advocates the importance of digital preservation in the museum area. In this chapter, we first compare the preservation requirements between physical collections and digital objects, and illustrate the relationship between management methods and preservation conditions, and then indicate that unsuitable preservation methods may raise certain security issues. This is followed by the description of several strategies that help to improve the preservation of digital collection available for the public over the long term. The current study of user experience will also be discussed in this chapter. The last section concludes the chapter with a summary and points out the gaps that require further research.

Chapter 3 explores the literature that provides an insight into current museum digitization efforts by looking at some practical examples of museum digitization and research projects from several major museums around the world. By reviewing and analysing the current progress of practical development in major organizations, we identify the potential gaps that could be filled in this research.

In chapter 4, we introduce the domain of our design principles and framework based on the deficiencies that have been identified from the literature reviews. We describe the essential components of our prototype and briefly outline our idea of Personal Trajectory Tracing Assistance (PETTA) for enhancing museum on-site experience.

Chapter 5 discusses the museum digitization issue from different perspectives by focusing on the field studies of electronic devices in the cultural setting. It first points out the history of electronic devices and discusses several previous works related to AR and Semantic Web on museum digitalization, and then presents an analysis and survey on the usage of on-site mobile devices from the top 100 most visited museums based on the designed principles introduced from the previous

chapter. This survey not only provides insights into the current development of Audioguide and Multimediaguide, but also helps to expose the weakness of their usage in physical museums. It also helps to define the conceptual framework of our research prototype, which is further discussed in the next chapter.

Chapter 6 describes in detail about the design concepts and process that guide the implementation of the prototype: *Semantic Museum- A Personal Trajectory Tracing Assistance*, which consists of a front-end interactive interface, a middle data interchange platform, and a back-end semantic inference database.

The theories and concepts of Interaction Design that the system adopted are discussed in chapter 7, in which the concept of Interaction Design including Cognitive Psychology, User Interface, and Human-Computer Interaction (HCI) with its' five dimensions are introduced.

In chapter 8, we discuss in detail about each component of the prototype based on the framework introduced in chapter 4, and present the first round of usability test using card-sorting technique before proceeding to the second round of test presented in chapter 9.

In chapter 9, the entire system is examined by Cognitive Walkthrough method and then evaluated based on a quality scale survey of real users. The findings and their implications are discussed. The final chapter draws conclusions from the data analysis and discusses whether the research questions have been answered. We also present a reflection on the research hypothesis and a summary of our contributions.

## 2. Current Challenges of Digital Curation

### 2.1 Introduction

Technology and societal impact play a complementary role to each other in museum digitization. The value and function of cultural heritage is realized through knowledge sharing and exchange of ideas. Hence, the focus of the digital museum should be on the visitor's experience rather than the technology itself. However, without the aid of advanced technology, such a goal cannot be realized effectively. Therefore, the challenges involved in the creation of digital museums can be divided into two dimensions: the use of technologies and the enhancement of user experience. In the past, the technical dimension has been the primary focus of museum digitization. Issues ranging from the imaging and digitization of artefacts to data management have been extensively researched (Cameron, 2010; Carrozzino et al., 2008; Kellogg Smith, 2006; Wei, 2010). It is true that a successful digital museum requires good technology; it is also true that this success cannot come without considering the important aspect of sharing cultural heritage through effective user experience.

For the technology dimension, digital objects have increased in status as part of museum collection due to the improvement in production process, increase in investment, and the positive value it generates. In order to extend the life of these

objects, most research has focused on the areas of preservation, the ease of digitization, accuracy, copyright protection, and value adding in the following ways (Koller, Frischer, & Humphreys, 2009):

1. Preserving digitized contents so that they are available for the public over the long term.
2. Accelerate the process of digitization while maintaining accuracy at curation-level at the same time.
3. Commercialize the digitized contents while maintaining proper copyright protection.

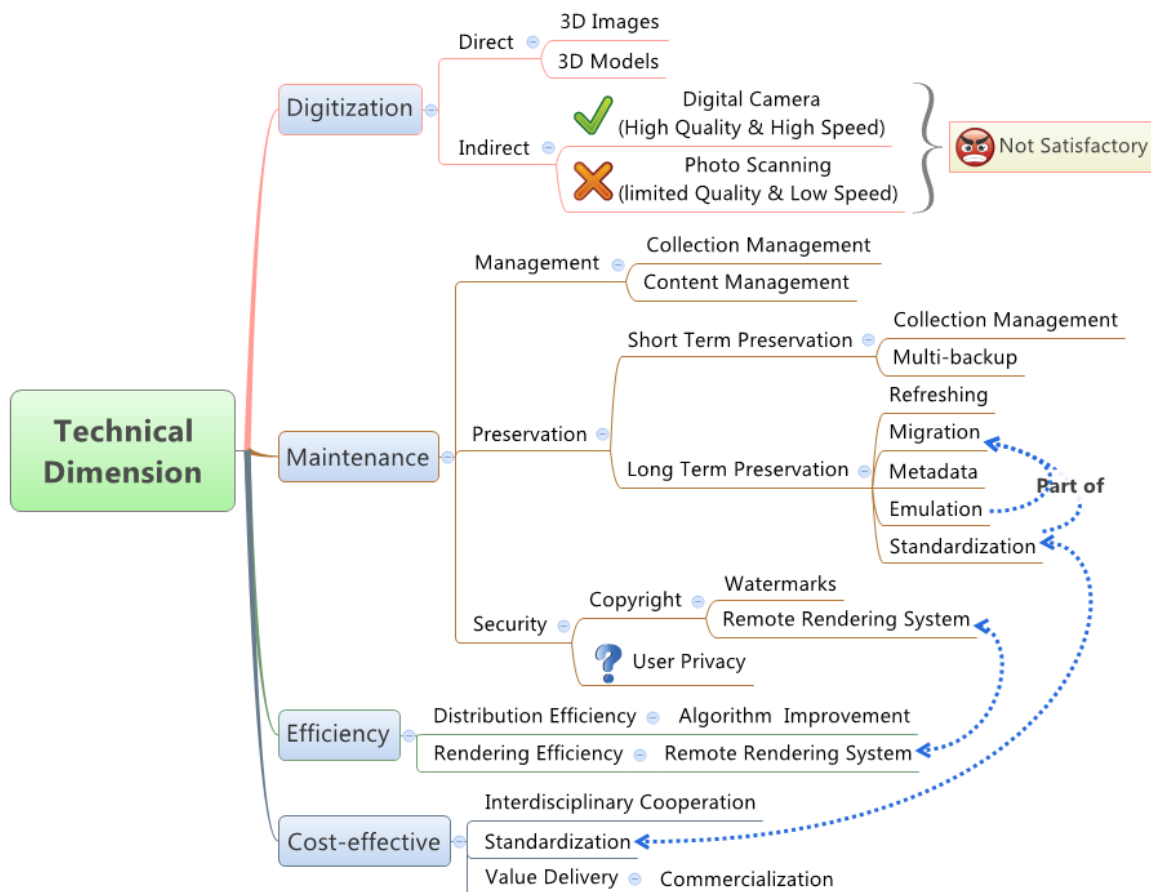


Figure 2-1 Different aspects of digital curation from the technical dimension.

The problems arising from some of the aspects above can be resolved by well-developed legislation and continual improvement in technology as shown in

Figure 2-1. For instance, through appropriate commercialization of digitized heritage collections, value delivery<sup>3</sup> can be increased for allowing more public exposure. The production speed can also be optimized by improving the rendering techniques (Wei, 2010). However, new challenges often arise with the application of new technologies. The digital museum is still facing some potential problems, especially on the issue of long-term preservation.

For the user experience dimension, digital museum implementations such as museum website and mobile App have been used to replace the concrete building and its function. However, we are living in a world where the fast growth of technology and the Internet have raised the expectation about the function of digital museum compared to a decade ago. Figure 2-2 shows a summary of different types of user experience discussed by Cameron (2010), Karakatsiotis, Oberlander, and Isard (2008), and Stuer and Meersman (2001), where different people expect different functions in a museum. A simple replacement of the display environment from physical to digital is unable to meet the need of different users. Hence, remodelling the function or role of digital museum for enhancing, engaging, and enlightening the user experience has become a major task. In this thesis I will focus on this dimension to facilitate the development of visit experience in museum and art gallery.

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<sup>3</sup> Value delivery refers to the process of generating extra functionalities, purpose, and values from the existing digital collections.

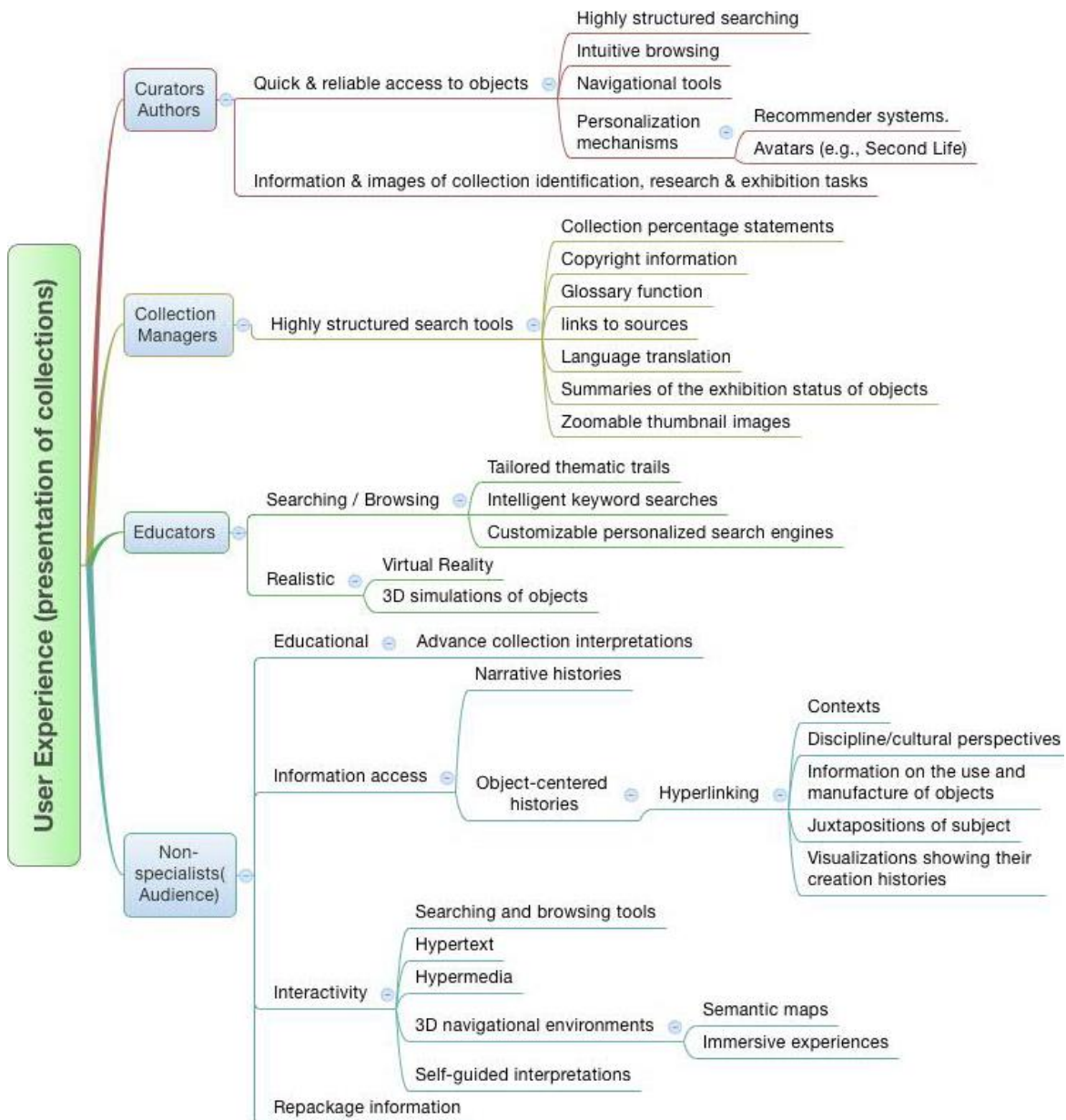


Figure 2-2 Functional need of different user groups in a museum.

Analysing the challenges and limitations of digitization is a crucial step in the development of digital curation. In the implementation of the digital museum, the relationship between people and collections is more important than the collection itself. Therefore, with respect to the aim of digitization and the problems being faced, we have identified three main challenges: the process of digitization, the ease of maintenance, and the enhancement of user experience.



## 2.2 Digitization - direct or indirect?

The issue of seeking a quality production method within budget is always raised by museum authorities to generate digital collections, as major projects of digital curation are usually funded by the governments with finite budget. It means that the authorities need to have ability to digitize objects efficiently with the limited resources and support. However, according to the National Library of Australia (2003), digital projects are often delayed due to immature technologies and unforeseen problems. Therefore, it is necessary to clarify the process of digitization before attempting to enhance the user experience factor. In the past, the indirect methods of digitization such as photo taking followed by digital scanning is the main option for the digital museum (Cheung & Yang, 2005). It gives operator easy access to the digitization process without requiring much technical background. Nevertheless, indirect digitization has brought some disadvantages. The issue of image quality cannot be overcome and the digitization efficiency is also potentially reduced by the cumbersome process. Moreover, the predominantly 2D presentation does not allow any interaction, which limits the capability of knowledge sharing in the digital museum.

The solutions of these issues have been widely deliberated over different discussions. The notion of direct digitization has been proposed. Traditional reflex equipment and scanner have been gradually replaced by the digital camera and 3D numerical framework. In contrast with the indirect mode, digital photography and three-dimensional digital modelling environment are able to decrease the production time by creating immediate digital copies, as well as decrease the storage space by removing the use of films and photos. It not only avoids second-order distortion during the production process, but also ensures flexible use of digital materials by holding native high-resolution images and 3D virtual models, as the data can be transferred into diverse mediums and usage such as the retrieval of metadata in Semantic Web, the integration of Virtual Reality (VR), and the commercialization of digital content.

Although direct digitization has become a prominent practice recently, new problems have emerged, such as the accuracy of 3D object, and the speed of network and modelling process. In the issue of 3D object presentation and modelling process, the details of digital objects such as bump and texture are usually modelled using surfaces with low polygon count due to the transmission speed limitation of the Internet. This limitation means that visitors cannot enjoy the vividness of object when viewing the digital object. It fails to meet the expectation of visitors wishing to experience the realistic effect of digital objects. As Marty (2008) observed, the majority of visitors expect that the realism of a digital museum has to reach beyond the traditional museum.

The issue of network speed can be divided into two aspects, the object loading speed and the speed of digital production. Wei (2010) claimed that high-resolution 3D models are comprehensively adopted on the Internet for visualization by digital museums and art galleries. However, he also indicated that the amount of data is usually too huge to download from the server's-side. Hence, developing modelling techniques that speed up loading time will become a crucial factor for digital curation. Besides the speed of production, museum digitization should also be concerned with the quality of the data obtained and their ease of use.

A number of strategies and approaches have been proposed to address the above issues for different applications. For example, the technique of Normal Mapping is used to balance the quality of 3D image and the Internet transmission speed in the online game area. Another attempt on these issues is by using advanced algorithm (Wei, 2010), which for example, uses progressive coding to improve the quality of object transmission. The future effort of digitization in museum and art gallery should be concentrated on the faithful representation and flexible use of digital objects.

## 2.3 Collection management and security issues

Content management is always linked to preservation issues. A meticulous management structure may help to extend the life-cycle of digital collections by following a standard operating procedure. However, the preservation of digital collections is confronted with various contradictions, such as storage and accessibility. With the large amount of data, digital collections not only have to be stored in a suitable way to keep them from disintegration, but also to allow them to be as accessible as possible (Guttenbrunner, Becker, & Rauber, 2010; Webb & National Library of Australia, 2003). With the vast amount of digital content, the ease of use and reuse of these resources have become difficult tasks for administrators or curators. Hence, the challenge involved in digital preservation can also be divided into two aspects: the development of digital content management and the issue of security.

In the past, the creation of digitized collection is designed to address the inaccessibility of collection warehouse in which visitors are unable to freely approach the collection and information that they are interested in. Digital content management such as online digital replicas and retrieval databases in this way provide an unprecedented prospect for museum authorities and their visitors. It not only allows visitors to obtain valuable knowledge from the digital collection, but also allows curator to manage the exhibits easily. According to Pallud & Monod (2010), over 80 percent of respondents surveyed agreed with the contribution and the benefits that museum digitization brings. Acting in the role of information provider, Cameron (2010) suggested that the digitized content and the retrieval systems can bring additional knowledge and insight and provide opportunity to integrated with different specialized fields such as archaeology, architecture, and education.

Although a fully equipped digital framework can extend the function of museum and art gallery, the issues that arise from the development of collection management and related security problems still need to be dealt with. Currently, different

organizations use their own standards to manage their digital collections due to different budget constraints and safety consideration as collections are often treated as important private properties of the museum. Hence, digital resources are frequently created in different formats on different platforms. As a result, this incompatibility of digital environment may hinder the cooperation between organizations as the digitized object can only be accessed by a limited number of proprietary systems. This would reduce the life-cycle of digital collections if the maintenance of the system is no longer supported. In addition, this would also decrease the opportunities of intercommunication, if the system is incompatible between different museums.

There are also other concerns of data security and criminal issues, which arise due to the portable and replicable nature of digital collections. Koller (2009) pointed out that the security problem may influence the volitional contribution of digital heritage. Content developers or cultural organizations will be loath to invest in digitization if digitized contents do not have adequate security protection. Digital information is different from their physical counterpart. It can be copied, moved, and distributed easily. Thus, it has become a target for unlawful persons to seek profit. The most recent case is the event of stealing and selling unauthorized digital copies to other countries by two assistant researchers from the National Palace Museum in Taiwan (Shiao-tien, Yi-han, & Hsu, 2011).

Although adequate security protection may improve the willingness of stakeholders to turn to digital preservation, security mechanism increases the difficulty of long-term preservation due to the continuous evolution of security solutions. New security strategies may not be compatible with the older preservation methods. Hence, in order to make the collections usable without the loss of security protection, the adoption of a unified standard is a priority in digital collection creation. Several conceptual experiments have been proposed to ensure the security of digital contents. Two examples are the use of remote rendering system (Koller, Turitzin, Levoy, & Tarini, 2004) and watermarking (Koller et al., 2009).

### 2.3.1 Remote rendering system

Remote rendering system guarantees that the digital collection can be accessed by visitors without it being maliciously recorded or copied. One such system is developed by Stanford University in 2001, supported by the Max Planck Centre for Visual Computing and Communication (Koller et al., 2004). In this system, the digital collection is represented as a low-resolution geometry on the client. After manipulations such as rotation and scaling, the corresponding parameters are passed to the server for high-resolution rendering. When an image is sent back to the client, the low geometry representation will be replaced by a high-resolution image. In this way, the digital information will be protected and the user is unable to access the original digital contents.

Despite the research result showing that this new type of visit is getting positive feedback from the users, some concerns still need to be addressed. The result of this approach indicated that the efficiency and performance of the system would be very dependent on the quality of the network, the number of CPU and GPU in the server, and the stability of the program. The user's experience can therefore be affected by these latencies between the client and the server. For this reason, it might not be suitable for long-term preservation in which the factor of migration is a priority.

### 2.3.2 Watermarking

The development of watermark system can be seen as an early application of digital preservation (van Schyndel, Tirkel, & Osborne, 1994). According to Sharkas, a digital watermark is a:

“Signal permanently embedded into a digital image that can be detected or extracted later by means of some operations for authentication purposes.” (Sharkas & ElShafie, 2005)

The specific features of Invisibility, Security, Oblivious, Unambiguity, and Robustness allow digital data to be protected during their distribution and preservation (C. Hsu, 2006). Some technical solutions have been introduced to hide information into the digital material for security purpose. For example, the semi-fragile watermarks, the dual watermark, and the Elliptic Curve Cryptosystems (C. Hsu, 2006; Koblitz, 1987; Liu, 2002; Nyeem & Boles, 2012; Shen & Chen, 2012).

Different types of watermarks have different advantages and disadvantages. The common benefit of watermarking is that extra security information can be embedded in the target collections without significantly changing the original appearance. The commercial and cultural value can therefore be retained by this method. However, some potential drawbacks exist. First, the image quality will be reduced by a poor encryption algorithm, which will also increase the risk of malicious decryption. Second, the user will be deceived if the original watermark is covered by another watermark (C. T. Hsu & Wu, 1999; Lu, Huang, & Sze, 2000). Finally, the lack of a backup of the watermark pattern may cause the problem of deadlock<sup>4</sup>. Users will be unable to identify which watermark is real if there is more than one mark in the target collection (Tsai & Cheng, 2005).

## 2.4 Preservation

Following the discussion of collection management in museum digitization, it can be seen that the preservation, particular long-term preservation is a critical technical issue that impacts the development of digital curation. According to the Digital Preservation Handbook published by Digital Preservation Coalition (2008), the general purpose of digital preservation is to secure a digital object from the potential media failure and technological change such as system update or obsolete

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<sup>4</sup> Deadlock problem: the problem of deadlock in the watermark system is to add extra marks based on the original content for confusing users to discriminate the authentic mark.

equipment, or coping with the increasing numbers of objects. In this section, we extend this discussion comprehensively by first comparing the differences between physical conservation and digital preservation in the museum area, and then provide several solutions to address the issues of long-term preservation in digital curation.

### **2.4.1 Physical conservation versus digital preservation**

In the past, museum conservation and management involved securing and storing the collections in a thermostatic, dust-free chamber or reducing the risk of unexpected damage by controlling the duration of the exhibition. According to Brimblecombe (1990), traditional museum conservation depends on the natural environment of the museum, such as humidity, temperature, light, and pollution. Therefore, museum collections are always exhibited in a showcase with dim light away from the visitors with minimum interaction and description. The purpose of this is to prevent the collections from weathering and erosion. In contrast to digital preservation, physical storage methods are relatively straightforward and potential damages can be inspected and repaired by visual observation.

The shift from physical object to digital form has changed the pattern of museum collection dramatically. Hodge (2000) pointed out that the life-cycle of digital information, such as creation, acquisition, cataloguing, identification, preservation, storage, and access in the digital archive system, is very different from the traditional printed materials and physical objects which are visible, touchable, and repairable. With respect to the environment of preservation, the storage mediums such as hard drive or disc also have their own life-cycle compared to the management software discussed previously. This may raise the compatibility issue between different systems to restrict the effectiveness of digital preservation, as a file created on an old system might not be readable on a new system. Based on the above discussion, digital preservation not only has to concern with not only the integrity of digital objects but also the evolution of technology and the degradation of storage mediums.

## 2.4.2 Long-term preservation of digital curation

The fundamental function of the digital museum is to ensure the availability of digital collections for public access over the long-term. According to Koller (2009), 94% of respondents in a year-long survey claimed that long-term preservation is one of the vital elements in the development of museum digitization. Hence, the preservation of digital information has become an important aspect of the digital museum.

From the technical point of view, several state-of-the-art strategies have been suggested in the past decades. Most of them are focused on library application, such as the preservation of pictures and printed materials (Heslop, Davis, Wilson, & Australia, 2002; Webb & National Library of Australia, 2003). Nevertheless, some of these solutions share their common interests in digital museum. According to the development director of Finland National Library Juha Hakala (2000), the potential strategies of refreshing, migration, emulation, and metadata may assist digital information to address the preservation issues. Guttenbrunner and his colleague (2010) have advocated the importance of emulation in the museum setting, and Döller & Coquil (2010) also affirmed that metadata is a suitable method for preserving digital heritages. Moreover, standardization, encapsulation, and system preservation have been suggested by Waugh and his colleagues (2000) from the CSIRO (Commonwealth Scientific and Industrial Research Organization). In these strategies, the proposition of standardization is recommended by many digital museum projects such as The Memory of the World, which is conducted by the United Nations Educational, Scientific and Cultural Organization (UNESCO) (2010b). Although several solutions have been claimed as important for their contribution, there are still some potential gaps needing to be filled. We discuss some of these solutions below.

### **(a) Refreshing**

The method of refreshing is the easiest and fastest way to preserve digital



collections. Moore's law (1998) predicted that the rate of technological advancement can be expected to double every eighteen months. Based on this speed, the current storage mediums will be unable to be read or written in the future. In this way, data information will therefore be lost unexpectedly owing to the rapid change of technologies. Hence, refreshing the storage mediums becomes an important consideration. Through the continual update of storage mediums, digital information accessibility can be assured for the life-cycle of the data; for example, by replacing the data hard drive or disc every three or four years, or by backing up the data to different mediums.

The advantage of refreshing is that it can ensure the integrity of data information and reduce the technical threshold of preservation as refreshing involves just a simple data copy. However, as Hakala (2000) concluded, refreshing is "copying information without changing it". The issues of compatibility between system and data formats are still present in its content. Hence, risks remain when operating systems or data format is no longer supported. Furthermore, with the increase of data resources, the workflows of refreshing will also become heavier and difficult to manage. As a result, refreshing can just be considered as a short-term preservation strategy.

## **(b) Migration**

The notion of migration is one of the initial suggestions of digital preservation. According to Waters and Garrett (1996), migration is a cyclic transfer of digital resources between different generations of systems, hardware, and software. Migration can be described as a full range of digital preservation process that could involve the concepts of refreshing, standardization, and encapsulation. The difference between refreshing and migration is migration ensures technical compatibility between systems and formats for future retrieval. Hence, many authorities have combined migration with other strategies for the configuration of digital preservation (Bearman, 1999).

The advantage of migration is that the original system does not need to be retained by the administrators. The cost needed to maintain the original format therefore is no longer there. Using data migration, digital collection can also have the flexibility to move freely between different museums and art galleries. However, some inherent disadvantages and limitations have also been noted. For example, the rate of file damage will increase. Waugh (2000) pointed out, due to the constant change of data format, it would be difficult to determine the health of the data; hence, the integrity of digital information may be compromised during data transformation. In addition, migration is unsuitable for data, which have been lost in their original format because further degradation might occur with subsequent migrations. Nevertheless, under some conditions, migration would be a useful strategy for digital preservation.

### **(c) Emulation and System Preservation**

Emulation, for example moving the whole architecture of a digital system in a customized environment to a new system, allows the original system to be operated without the original supported hardware. The idea of emulation is to make the new computer system mimic the operation of the old computer system by using an intermediary emulator. This allows new systems to render images and content from old systems via virtual operation. Consequently, the simulation can not only ensure the integrity of the digital information, but also reproduce the look, feel, and behaviour of the original content. It returns digital information to its original appearance and ensure complete reproducibility of the digital information on a new computer.

Although emulation seems a grassroots solution for digital preservation, some potential challenges still need to be addressed. One of the major challenges is the stability of emulators. Ouyang (2003) has noted in his research that unpredictable system bugs have triggered public attention during the crisis of Y2K in the beginning of the 21 century. Under this threat, the whole data information will disappear suddenly if the intermediary is no longer available.

Another challenge is the simulation quality of the emulator. From Guttenbrunner's survey (2010), many emulators are unable to fully reproduce the original environment. Hence, the outcome of digital preservation may be affected by the low quality emulators. In addition, he also cautions that due to the lack of practical experience in its application, emulation may not be currently suitable for long-term digital preservation.

#### **(d) Metadata**

The use of metadata, which focuses on the preservation of data meaning by providing a description and annotation of the data, is a priority of museum preservation. Lorie (2001) separated the structure of digital information into two categories: data and algorithm. He mentioned that, to ensure the survival of data into the future, data preservation should be accomplished by the use of metadata and emulation should be used to manage the preservation of codes or programs. In this way, information such as the author's details, the collection and its history, and the creative concept can be recorded in a machine-readable format. From the preservation perspective, separate storage of data and metadata may reduce the risk of data loss and increase the flexible use of information.

Some techniques are designed to reach this goal; one of the applications is the use of Semantic Web, which is mainly adopted by web search engines for creating machine-readable web contents. Through the systematic ontologies, digital information will become structured semantic annotation. The advantage of this is to create a standard format across different systems and expand its use to various purposes, such as personalization, and recommender system. In this way, the information life-cycle can be extended. However, due to the lack of real application and the constant change of ontology description, Semantic Web is still unable to function as a preservation method in the museum setting.

### **(e) Standardization**

Standardization, a basic requirement in metadata generation and content migration, is usually applied together with other preservation methods. Standardization focuses on creating a standard format of data contents, such as code, format, metadata standards, data exchange specifications, and database structure. In the past, standard format has rarely been discussed due to security concern. The entire content of the digital museum often involves different information from various sources. Therefore, information collection has always been a difficult task for individuals or single organizations. This situation has also impacted on the data storage. The dispersed and incompatible data format will increase the difficulty of digital preservation. However, according to Boast (2002), standardization is now being embraced by some museum authorities to ensure the feasibility of file interchange between different organizations.

It is clear from the above discussion that in order to overcome the obstacle of long-term preservation, the establishment of metadata standards and interoperability mechanisms are the top priority. Once the data can be read by different machines, the preservation aspect will be enhanced. However, some issues have arisen from the applications of standardization and security. For standardization, due to various standards evolving over time, the most difficult challenge is how to select a stable and appropriate standard specification for supporting a variety of cross-platform applications, and avoid data loss or derogation of original meaning during standard transformation. The security concern, as we have mentioned at the beginning of this chapter, is another issue for the standardized data. By enduing the intercommunication feature, the interoperable file format may increase the risk of malicious duplication and alteration.

## **2.5 User experience**

User experience has been considered as an indispensable factor by academic

researchers and curators in museum digitization in recent years. According to Beer (1987), museum visitors spend less than one minute on each collection in on-site. Thus, how to captivate visitors by extending the time of collection appreciation and enhancing their knowledge by adopting various machineries has become a new field of research in digital curation. Some research results have suggested that the museum experience can be boosted by an interactive and immersive environment (Y. Wang, Stash, & Sambeek, 2009). Consequently, it can be expected that the traditional method of masterworks' description will be replaced by other methods that enhance the sensory impact and the real experience of the visitors. In the next chapter, we focus on this dimension by examining several museum and research projects. The purpose is to define problems that may impact the user experience when applying digital technologies.

## 2.6 Discussion

In this chapter, we have introduced common approaches for museum digitization, and discussed current efforts to address the challenges in the cultural heritage settings, focusing on the issues of collection management and preservation. Although digital preservation has been addressed from different aspects, many potential problems still remain. For instance, standardization seems to be a possible solution, but it increases the cost of production (Boast & Bravo, 2002). The use of emulation not only has to be concerned with the accuracy of emulators, but also with the lack of real working examples (Guttenbrunner et al., 2010; Hoeven & Lohman, 2007). The use of metadata affects standardization due to the different existing ontology formats. For the issue of security, the quality of digital data is impacted by the digital security mechanism used, and sophisticated protection architecture may sacrifice user experience. If these challenges can be addressed successfully, the development of digital curation can not only promote the role of museum in this digital era but also boost the value of cultural heritage more than ever before.

Thus, we conclude that the process of digitization will need to balance the quality of digitization with the efficiency of digitization; a good management framework will need to balance the issue of security with the ease of distribution of digital contents; a well-personalized system will need to confront the issue of privacy with the efficiency of usage; a flexible data format will need to deal with the ease of quality control on different platforms.

We also noted that previous research on museum digitization often accentuates the technical aspects and neglects the importance of the intangible cultural meanings. We believe the future work of museum digitization should highlight the connection and relationship between tangible and intangible aspects, and extends the life-cycle of the digitized objects while retaining its cultural implications. We also believe that on-site museum experience complemented by the use of modern information technology would enhance visitors' appreciation of cultural heritage.

# 3.Existing Museum Digitization Projects

## 3.1 Introduction

The aspect of user experience is highly significant in museum digitization (Li, Liew, & Su, 2012). However, research in this aspect is still relatively few at present. Following the discussion in chapter 2, this chapter focuses on the dimension of user experience by investigating several existing digital museum projects.

Since the 1992 UNESCO project of “Memory of the World”, a number of information-urbanized nations have been developing digital curation programs. Some major projects are: the digital project of The Louvre Museum, which is managed by The Centre for Research and Restoration of Museums of France (C2RMF) (Lahanier, Schmitt, Le Boeuf, & Aitken, 2003); the digitization of The National Gallery and The British Museum; The International Dunhuang Project (IDP), which is funded by The British Library in UK (Gregory & Healey, 2007); The Metropolitan Museum of Art’s “Timeline of Art History”; and the national projects of digital archive for National Palace Museum in Taiwan. Next section will discuss some of these organizations and independent projects that address the enhancement of user experience in museum digitization.

### 3.1.1 The Louvre Museum

The Louvre, which is the most visited repository, has a leading position in the world of museum according to The Art Newspaper in London (Arad et al., 2010). The collection digitization project has been running for over 20 years with the support from government. The role of the commission during this period is mainly focused on the digitization of paintings and the technique of multimedia display. For this purpose, the entire digital resources are incorporated within the official website as well as cross-platform applications such as mobile Apps. It allows digitized information such as 3D collections and descriptions to be easily accessed on the Internet or browsed on portable devices.

In order to fulfil the role of cultural communicator, the current achievements of digitization in The Louvre consist of several functions that include:

- I. The unit of “A Closer Look”, which can be viewed as a doorway that leads the novice into appreciation of museum exhibits. Visitors can receive voice-guided tours and animation about a collection with detailed information such as the size of the object and its age. It also allows users to look at the background of the collection to obtain information about the author via interactive multimedia. In this way, the element of interaction is attempted.
- II. The unit of “Thematic Mini-Sites”, which encompasses a series of mini-sites to cater for the needs of different users. Users are able to get into various themes faster and to retrieve specific exhibit quickly through an interactive interface. In this attempt, a base collection management system is presented to support data retrieval.
- III. The unit of “Online Tours”, which acts as an online personal tour agent for people who cannot visit on-site or who need in-depth insight of specific



collections. By the end of 2012, there are just three thematic tours available, which include Egyptian Antiquities, Remains of the Louvre's Moat, and Galerie d'Apollon. Based on these tours, the efforts of museum personalization can be explored.

- IV. The unit of “Collection Database and Selected Works”, which makes available to visitors or researchers to search various digital collections by keywords, accession numbers, or pre-classification collections. By the middle of 2012, 6 databases and 29 classifications have been published online for public searching. It provides an advance search experience for people who need specific information related to a particular object.

Comparing with other digital projects of this survey, The Louvre can be considered as a model of the digital museum in which it has tried to equally stress the aspects of user experience and technology. However, with the restricted functionality of thematic tours and the non-comprehensive mini-sites, the application of personalization remains in the embryonic stage. Moreover, visitors are restricted to observing the collection on pre-set angles as the entire digital collections are presented by a series of 2D images.

### **3.1.2 The British Museum**

The development of digitization in The British Museum has been ongoing for over a decade since the end of last century owing to the celebration of the 250th anniversary of the museum. The Collection Database project, previously called Compass (Collections Multimedia Public Access System), is a result of 10 years' work. It has three types of interfaces: on-site, web-base, and child-centred, to cater for different group of visitors. The first prototype was launched in 1997. The goal is to build a searchable collection database for research and exhibition.

According to the recent report and account from The British Museum, the online museum collections have received around 1.5 million visits each month. The total digital collection has reached two million visits at the end of 2011, from the masterworks of Egypt and Sudan to a range of Asia artefacts. Although the project has been in operation for over 10 years, the entire system is still in its early stages due to the huge quantity of collections. With the coming of the new century, the museum is constantly adding new contents to the database every week. The expected version of Collections Database would include every collections in the museum (The British Museum, 2012).

In recent year, multimedia guide devices are used in the British museum to enhance the user experience. The purpose of this attempt is to provide additional information to complement the existing on-site explanation by allowing users to enter the number that is tagged on the exhibit into a hand-held device during their journey. With the device, visitors receive additional information on the screen or by voice for more than 200 objects in over 60 galleries (McDaid, Filippini-Fantoni, & Cock, 2011). Meanwhile, the device also provides an interactive map for visitor to quickly navigate their way within the museum. The portable device not only offers a visual tour guide for guests with maximum flexibility, but also provides customized visit using internal GPS technology. In brief, the British Museum has endeavoured to provide an advanced in-house and online experience for visitors by applying complex database and cutting-edge equipment to meet diversified interests of visitors. However, with the limited amount of digital collections and screen presentation in the multimedia guides, the demand of the visitors cannot be fully met.

### **3.1.3 The Metropolitan Museum of Art**

The Metropolitan Museum of Art in New York has a history of more than 130 years. According to the annual report published by the official authority, the number

of on-site collections will reach over two million in next ten years (The Metropolitan Museum of Art, 2010). Based on this growth rate, over 7000 works have been digitized for public access over the Internet that not only includes information of the exhibits and conventions, but also a collection searching tool called Timeline of Art History that illustrates the history of the collections by digital pictures from two million-year BC to the present. At the same time, online social networks such as Facebook, Twitter, Flickr, YouTube and iTunes U have been used to bring attention to the museum community. The intention is to intensify the communication outside the museum's official website via existing social networking sites. The amount of digital objects will be continually increased in the future due to the new department of digital media that was unveiled in 2010.

On the efforts of museum personalization and interaction, The Metropolitan Museum has administered a number of projects to attain these goals. Two examples are the Met project and the social tagging experiment:

### *I. The Met project*

The Met website is an online collection database. It enhances the pre-visit experience by presenting the collection's information in different media formats such as video, audio and podcasts. MyMet is a customized museum record system in the Met project, which enables adding information of digital collection into a personal record based on the user preference and demand. At the same time, guests may also arrange their own on-site visit from the current events or programs.

### *II. Social tagging*

The experiment of social tagging was a trial research directed by The Metropolitan Museum in 2005. It was designed to make the museum collection more accessible and relevant to their visitors by inquiring visitors with a series of keywords from 30 museum collections. The outcome was

collated with existing curatorial cataloguing from the official collections system to enrich the search results (Chun, Cherry, Hiwiler, Trant, & Wyman, 2006).

Although the authority has endeavoured to stress both the factors of personalization and interaction by various popular social media and online presentation, the on-site experience is still very limited, as the personalized information need to be generated manually before visiting.

### **3.1.4 National Palace Museum (NPM) of Taiwan**

In Taiwan, the most famous program is the Digital Archives Project conducted by NPM, in which multiple phases are created and supported by the national government since 2004. The first phase focused on the research and development of digital archives system, which has been completed in 2008. The Phase II was centring on the establishment of Taiwan e-Learning and Digital Archives Program, which was started after the completion of Phase I and is being planned to be finished in 2012. The major task of this phase was digitizing all heritages at NPM (National Palace Museum, 2012b). The entire content of this project follows from the classification of the NPM collection and the large inventory. The authority holds a great number of complex classifications, and the categories can be subdivided into different type of collections such as costume and accessories, painting and calligraphy, as well as ancient Chinese documents across different dynasties. The total number of the collections in the museum is 682,061 volumes, including 70,265 utensils by the end of December 2010 (National Palace Museum, 2010).

With the intention of managing such a huge number of collections, the institute has a framework for creating a group of digital databases. It contains Antiquities Archives Data Search System, Painting and Calligraphy Archives Data Search System, as well as the Qing Palace Archives and Palace Memorials Databank, which are all up

to date and are proceeding for incorporation into The Digital Archives Project (DAP). All contents are available for free public access. The motivation of this project is to promote the relationship connecting digital collections and users by creating a database for long-term preservation, as well as promoting the capacity of user experience for researchers and the creative industries. This has not only created a wide-range of synergy, but also raised the international reputation of the museum (Chou, 2010).

Comparing with other major museums in this survey, the NPM is more concerned about the elements of education and the capabilities of repacking the collections in the museum digitalization. For educational purpose, in order to fulfil the role of a learning institution and arouse the interest of visitor's participation, the museum has attempted to turn the digital collections and its historical background from the traditional museum exhibit to vivid three-dimensional movies called "Adventure in NPM". With anaglyph 3D glasses, visitors experience the most realistic vision of digital relics and the stories behind the collections by introducing these relics digitally in their original style (National Palace Museum, 2012a). For the aspect of repacking, the authority has launched a project called 3D Digital Resource Sharing Applications, in which the digital resources can be used publicly in academic research, education and promotion, publishing, video playback, commercial use, or any other purposes to increase the value of the digitalized objects. However, these digital resources are only stressed on virtual presentation. It means that, there is no on-site digital information complementing the physical exhibits in the current digitization effort.

### 3.2 Digital Projects

After investigating several major museum digitization projects around the world, it can be summarized that the current digital projects are dependent on government support with a limited budget. The digital implementations are often

confined to oversimplified way of expressions such as pre-record thematic tours and sites, and stress on online resources presentations. For a deeper understanding of the advance development in the field, we turn the focus to some cross-nations ongoing research projects. The purpose is to explore novel experimental ideas from different perspectives and identify the potential contributions that have not yet been approached.

### **3.2.1 CHESS (Cultural Heritage Experiences through Socio-personal interactions and Storytelling)**

CHESS is a research project co-funded by the European Commission. It is conducted by two European museums, the Acropolis Museum in Greece, and the Cité de l'Espace in France. The project aims to provide a concept of “adventure” for visitors to explore museum collections by following a series of defined stories. Each story is presented by a virtual persona through a storytelling interactive audio guide that shares the historical events and specific memories about the collections during the visit. The objective is to enhance the museum engagement by using personalized interactive storytelling. Regarding the system configuration, it consists of two modules: the CHESS Authoring Tool (CAT) that helps curators to create historical stories related to existing museum collections; and a mobile device that offers an interactive platform and correlative functions such as AR and in-store games for visitors to interact with the on-site collections (Katifori, Karvounis, & Kourtis, 2014).

#### *I. Curator experience*

The CHESS Authoring Tool (CAT) is a platform for curator to create, manage, and publish the CHESS EXPERIENCE (stories). Through the tool, curators can link a collection as a hotspot to stories based on its on-site location on the museum map. According to Katifori (2014), the CHESS stories can be implemented via different types of activities such as a simple audio guide, interactive games, AR and interactive images. With the

adoption of this tool, curators can easily create a set of visitor experience schemes for various purposes.

## *II. Visitor experience*

For the visitor experience, in order to obtain the users preference, visitors are required to log in with their social accounts such as Facebook or twitter and take a quick quiz in the CHESS website from home or at the museum before interaction with the system. By retrieving the personal profiles from the social websites and analysing the data from the quiz, the system will match the visitor with an appropriate persona and story, and then creates a list of potential collections of interest based on the identified story. During the visit, visitors are guided by a mobile device that stores matched story and the related collections information from the cloud, and can interact with mixed reality<sup>5</sup> such as AR and in-store games for gaining a better museum visiting experience.

The CHESS project is a research effort that provides a better experience for both museum authorities and visitors. In this attempt, although the preference metadata still rely on the input data from the visitors, a novel conceptual framework is provided for both curators and visitors to manage the current exhibitions and understand visitors' behaviours. Through the matched tours/stories and state-of-the-art technologies such as mobile devices and AR, a personal interactive museum experience can be implemented. Hence, such comprehensive framework will be taken into account in the construction of our research prototype design.

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<sup>5</sup> Mixed reality also calls hybrid reality which refers to the process of creating a new environments and visualizations from completely real through to completely virtual by encompassing AR and augmented virtuality (Milgram & Kishino, 1994).

### 3.2.2 CHIP (Cultural Heritage Information Presentation)

The CHIP is an interdisciplinary research project between information technology and museum masterpieces created by CATCH (Continuous Access to Cultural Heritage) program of NWO (The Netherlands Organization for Scientific Research) in Netherlands. It started in early 2005 and is conducted by the Technische Universiteit Eindhoven, the Telematica Instituut, and the Rijksmuseum, a Netherlands national arts and history museum in Amsterdam. The aim is to provide personalized experience for visitors to better understand the collections from the Rijksmuseum (Y. Wang et al., 2008, 2009).

The project is the combination of three components: Artwork Recommender, Tour Wizard and Sight Guide (Mobile Tour). It creates a pre-visit experience by allowing visitors to build a personal tour path by rating collections online, as well as offering a chance for visitors to review the collections which are of interest to them after they finish the on-site visit. We will describe these components in detail below to understand the pros and cons of the project.

#### *I. Artwork Recommender*

Artwork Recommender is a Web-based rating system built on the Semantic Web technologies. It provides an interactive platform for visitors to build their preference list by rating the collections online. Through this system, the semantic browsing, searching and semantic recommendations can be implemented.

#### *II. Tour Wizard*

Virtual Tour Wizard is a Web-based tool that helps visitors to general personalization tour paths based on the rating from Artwork Recommender. The output results can be either visualized on Google maps or a historical timeline provided by the project. This approach enhances personalization experience and encourages users to visit the physical museum after their online visit.



*III. Sight Guide* Sight Guide, also called Mobile Tour, is a PDA-based portable platform, which displays the collection information when the device is connected to the Internet. The platform is designed to complete several tasks when it is applied in the physical museum, such as downloading the tours from the Tour Wizard, synchronizing the user data, filtering the unavailable collections, and providing rough on-site navigation. During the visit, visitors can retrieve the collection information and local position using RFID reader to enhance the on-site museum experience.

The CHIP project can be regarded as a forerunner of collection recommendation in the cultural setting and an initial rudiment of our research. The intention is to build a bridge across the virtual and physical environment to enhance the museum experience. In some way, the Recommender delivers a strategy for visitors to build their unique personal museum. However, the passive method of data collection in this project (rating system) may limit the potential visiting experience as visitors may treat the process as besetment and refuse to follow the procedure. Thus, how to collect users' preference proactively has become one of the challenges that need to be addressed in our research.

### 3.3 Discussion

A survey on the digitization projects from different museums allows us to understand the current efforts in this field from both the practical and theoretical perspectives, and provides valuable insight about its development from the user-experience viewpoint. Clearly identifying factors affecting user experience can offer valuable guidelines to assist curators and researchers to construct a useful digitization framework. For the investigation of museum digitization, Table 3-1 summarizes several factors related to the user experience aspect. As can be seen in the table, none of digitization effort considers all factors during museum digitization. Although interaction and personalization have been addressed in many different

ways, some important concerns such as long-term preservation, repacking, cooperation between virtual and physical entities, still need to be addressed. Addressing these concerns adequately would increase the functionality of the physical museum and further enhance visitor's on-site experience. Thus, in this research, our prototype framework will be built based on these factors for dealing with museum user experience.

|                                                              | The Louvre<br>Museum | The British<br>Museum | The Metropolitan<br>Museum of Art | National Palace<br>Museum (Taiwan) |
|--------------------------------------------------------------|----------------------|-----------------------|-----------------------------------|------------------------------------|
| <b>Visualization</b>                                         | ■                    |                       | ■                                 |                                    |
| <b>Personalization</b>                                       | ■                    | ■                     | ■                                 |                                    |
| <b>Interaction</b>                                           | ■                    | ■                     | ■                                 | ■                                  |
| <b>Education</b>                                             |                      |                       | ■                                 | ■                                  |
| <b>Repacking</b>                                             |                      |                       |                                   | ■                                  |
| <b>Cooperation between<br/>Virtual and physical entities</b> |                      | ■                     |                                   |                                    |

Table 3-1 Approaches of user experience in different museums (Data collected in mid2012).

For the research projects of CHERS and CHIP, we have examined some practical ways to enhance the relationship between visitor and physical museum, and discussed the motivations that will be considered in our research methodology. We have also identified problems that need to be avoided in the research design. In the following chapters, these inspirations and identified problems will be collated into different perspectives for implementing a research prototype.

# 4. Articulating the Framework of User Experience in Museum Digitization

## 4.1 Introduction

Previous chapter introduced several strategies related to the enhancement of museum visitors' on-site experience. The facets of visualization, personalization, interaction, education, and repackaging are identified as five key factors that are important to museum authorities. This chapter discusses in detail about how these elements can offer visitors valuable experience and help to improve the communication between visitors, curators, and on-site museum space. The objective is to articulate a framework of principles for creating our prototype.

## 4.2 Visualization (Casual Information Visualization)

Visualization is the keystone of user experience in the field of digital museum. Previously, visualization systems were mostly exploited in the professional field as an overview provider through complex technology-based interface and interaction (Pousman, Stasko, & Mateas, 2007). For example, the Solid Software Xplorer (SolidSX) has been developed as a Windows tool of creating high-resolution image structures for users to understand and examine the applications that are designed by any type

of .NET languages. Crime mapping is a map adopting by law Enforcement Agencies (LEA) for showing and analysing different crime models.

However, the situation has been changing over the last decade. The concept of Casual Information Visualization (Casual InfoVis) has been promoted by the digital curation community. Casual InfoVis has been designed for visitors who do not have special qualifications or only visit museums casually (Hinrichs, Schmidt, & Carpendale, 2008). The view of this insight comes from the edification of other information systems, social visualization and artists' visual works. The difference between Casual InfoVis system and traditional InfoVis can be attributed to differences in user population, usage pattern, data type, as well as goals in which the information can be illustrated by using computer-mediated applications (Pousman et al., 2007).

Casual InfoVis can be described as a rudiment of utopia in the presentation of museum digitization. However, the implementation and outcome of this concept still rely on the integration of different components such as interactive interface, database and personalized framework. With the progress of digital museum development, the developers and curators should keep this notion in mind in order to assess visitors' behaviour effectively for providing the best solution.

## 4.3 Personalization

The function of personalization is one of the fundamental components for the achievement of digital museums. Proper use of this concept could not only provide curators with better opportunities to understand the needs of visitors, but also cultivate their potential devotion. As Riecken (2000) indicated, personalized attention is a way of "building customer loyalty by establishing a one-to-one relation". In addition, personalization may also reduce the financial pressure in the operation of museum management. How to use the limited resources to connect

with visitors has become the major concern (Fantoni, 2002). For instance, museums could redesign the on-site tour paths to attract visitors by using personalized technologies; or choose the most popular collections for exhibition via repackaging. In order to accomplish this objective, several efforts in museum personalization have been proposed. These include, for example, the CHERS and CHIP projects that were introduced in the last chapter, and the Piggy Bank Project. The latter is a sub-work of Simile project (Semantic Interoperability of Metadata and Information in unLike Environments) directed by the MIT Libraries and MIT CSAIL as a Firefox extension for user to collect digital contents from separate websites and then combine them together for further references (Huynh, Mazzocchi, & Karger, 2007). In spite of each project providing different features, the most noteworthy common feature of these efforts is the integration of the Semantic Web. This means that the personalization of items can be implemented by using highly semantic module.

### 4.3.1 Semantic Web

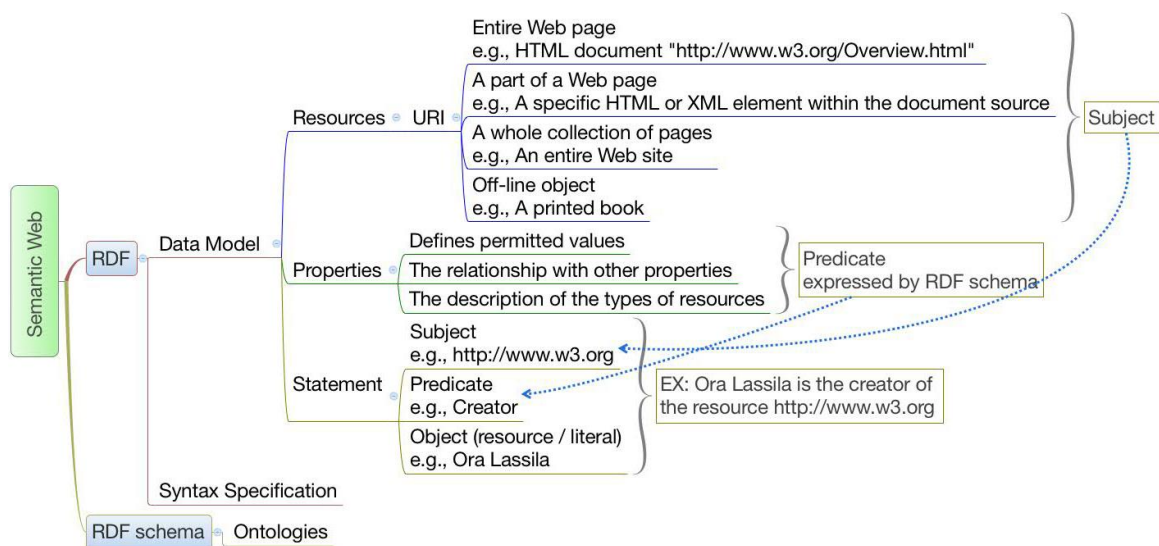


Figure 4-1 Framework of Semantic Web.

According to Tim Berners Lee, the Semantic Web is an extension of the web based on the fact that machines can better comprehend the metadata by giving a well-defined meaning to information. In the context of digital museum, this

technique is evolving from being museum dominance towards user centred collaborative filtering. The materialization of which could be involved in several modules, including Resource Description Framework (RDF), a data model that is used to carry a variety of metadata between resources (Lassila, 1999); Web Ontology Language (OWL), a basic ontology language that is clearly expressed in terms of proper nouns and the relationship between these terms (W3C, 2009); Ontology, a way of self-description adopted by XML and RDF that could make the connection between each individual in the web; and Simple Knowledge Organization System (SKOS), a language that is designed by RDF Schema for sharing and demonstrating controlled vocabularies (Miles & Bechhofer, 2008). Figure 4-1 describes the combination of different components of RDF in the framework of Semantic Web. For this framework, we adopt Cidoc-CRM as the main ontology in this research.

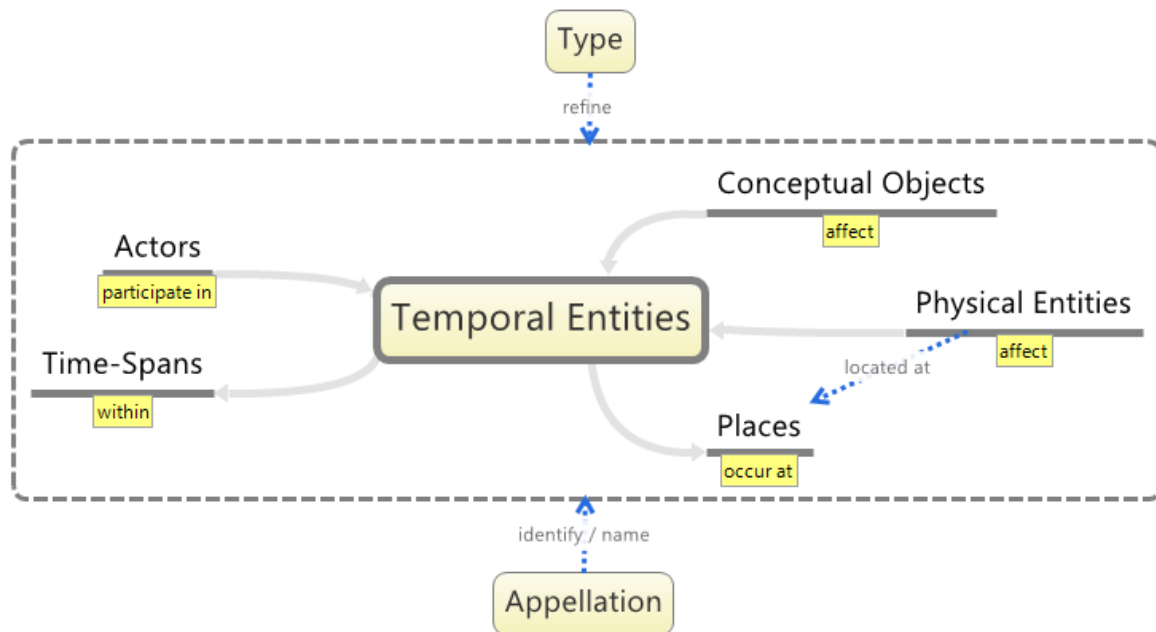


Figure 4-2 A qualitative metaschema of the Cidoc-CRM.

Cidoc-CRM is one of the ontologies created and managed by The Comité International pour la DOcumentation (Cidoc). The ontology is created by experts from the field of cultural heritage and technical personnel from one of the

committees in the International Council for Museums (ICOM). In 1996, the group of Documentation Standards in Cidoc began to develop the Conceptual Reference Model based on cultural heritage information. Through a decade of development and modification, the ontology of Cidoc-CRM has become an international standard in the field of cultural heritage (Cidoc-CRM, ISO21127) ("The CIDOC Conceptual Reference Model ," n.d.). The framework of this domain ontology can be found in Figure 4-2, and is aimed to identify the type and classification of cultural heritage information, which defines a conceptual framework of knowledge sharing that can be understood by human.

In this framework, properties such as Actors, Conceptual Objects, Physical Entities, Time-Sans, and Places are used to describe the Temporal Entities; all class may be identified by the Appellation such as names, titles, and names; the class can also be refined by Type for more detailed categories. The goal of this ontology is to connect the experts such as historians, archaeologists, or biologists, to information systems developers with the aim of communicating clearly without misunderstanding. Hence, in consideration of the following characteristics listed below, this ontology will be chosen as the fundamental semantic information in this research:

1. *The interchangeable format*

The initial format of Cidoc-CRM can be supported by XML and RDP. Therefore, conversion can be achieved between different semantic modules.

2. *The semantic description*

The information description of Cidoc-CRM is designed for application to digital collections. In this ontology, the essential information of the digital collection such as history, author, production process, archaeological and geographical data can be described. The relationship among different metadata such as event, time, and location can also be retrieval in this ontology.

Although the Semantic Web seems to be a beacon of museum personalization, it still has some potential drawbacks to be overcome, such as the issues of privacy, data security and immature ontologies. The role of Semantic Web in the museum context is to provide a way of analysing and understanding human behaviour while separating irrelevant personal details of the users. The questions of how to maintain information as a personal resource without privacy and security concerns, and how to define the ontology are not in the scope of this research.

## 4.4 Interaction and Education

Formerly, museum exhibitions tend to comprise of actual objects with limited explanations written by curators or reviewers on the display panels beside the objects or pre-record in the audio hand-held devices as a personal tutor during the visit. However, such styles of presentation has many negative aspects, such as creating distance between visitors and objects, as well as make people feeling more isolated as they do not have the opportunity to communicate with each other about the collections that they are interested in. Spasojevic and Kindberg (2001) pointed out that the expectation of museum exhibitions should be blended with extendable visiting experience, and appropriate interaction with real objects. Coulter-Smith (2006) also stressed the importance of interactive activities, which can lead arts into our lives by building a bridge between visitors and artworks. Therefore, the capacity of the museum should be like a "multi-dimensional educational institution", in which a visitor can retrieve the information for references, and approach the additional resources of the collections like in a tutorial. In relation to these aims, some techniques have been proposed to enrich the constituent of an interactive museum, such as Web-based construction, Virtual Reality (VR) or Augmented Reality (AR).

### 4.4.1 Augmented Reality

AR is an extension of VR system that can intermingle actual with virtual



environment for real-time interaction (Azuma, 1997). The platform is usually established by ActionScript3 (AS3) with integration of several external code libraries such as Flex SDK code library, Flash Augmented Reality code library (FLARToolkit), and Papervision3D code library (PV3D). The details of these libraries are listed as below:

*I. Flex SDK*

The Flex SDK, an Adobe open source standards-based language, is able to create a highly interactive and expressive application by offering an optimized cross platform framework for synergy between different designers, and extract data from various back-end sources and display them visually (SourceForge, n.d.). This allows visitors to customize the collections that they are interested in or navigate the path of art appreciation on-site. The adoption of this library in the implementation of AR is to manage the required embed metatag to import FLAR data files.

*II. Flash Augmented Reality (FLARToolkit)*

FLARToolkit, which is a Java ported version of ARToolKit, is developed by a Flash/ActionScript open source community called Spark Project. According to the project announcement (Spark project, n.d.), this Toolkit is able to “recognize the marker from input image and calculate its orientation and position in 3D world”. Hence, in this research, the role of the Toolkit is to detect the marker that is used to present the 3D collections.

*III. Papervision3D (PV3D)*

Papervision3D is an ActionScript code library based open-source real time render engine, which enables Flash projects to render 3D objects dynamically without pre-rendering. In this research, the 3D collection is built by external applications such as Maya or 3DS MAX, and then imported into Flash Builder for positioning and rendering of the 3D model.

Based on these techniques, the implementation of AR works towards filling the gap of traditional museums which do not offer sufficient interactive platform for visitors and artefacts. Some studies have been aimed at the application of AR to museum interaction. For instance, Flypad project was developed by The Mixed Reality Lab (MXR) in the University of Nottingham for a controversial arts centre called The Public in England. This project endeavoured to enhance the condition of interactivity by using the technique of AR, which allows users to control their avatar by operating different control panels, and to further improve the user experience (Flintham et al., 2011). Another example is the undertaking of the virtual showcase, which is a translucent display system using AR. It was first introduced at Vienna University of Technology in Austria, followed by the advance pattern, which was announced at Laval Virtual 2011 by the ESIEA engineering school in France (Bimber et al., 2003). The ambition of this system is to lay emphasis on the interaction between visitors and physical artefacts and break the barrier between virtual and actual museums by integrating the AR technology into a traditional museum showcase format.

Figure 4-3 to 4-5 summarizes the development of AR from the past decades. The techniques that are used in these approaches lead to a strategy to reach the goal of interaction and education in the physical museum. Unfortunately, according to these charts, on the embodiment of personalization, the pre-experience and after-experience of the visit are not contemplated in these systems. Thus, in order to strengthen the entire journey of the museum visitors, the aspect of personalization should be taken into account in the development of the interactivity process in the future.

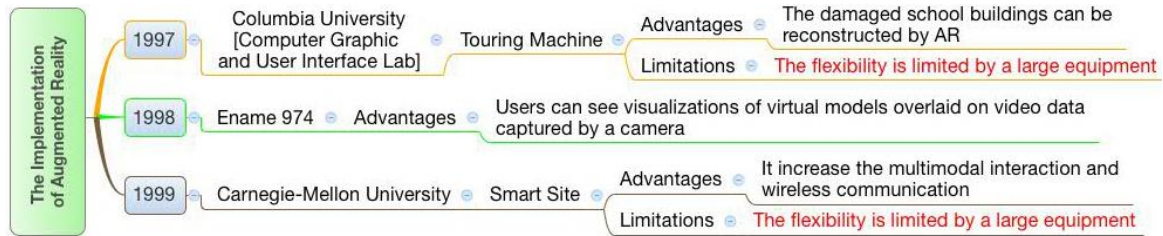


Figure 4-3 History on the development of AR before 2000 (see Figures References).

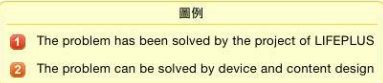
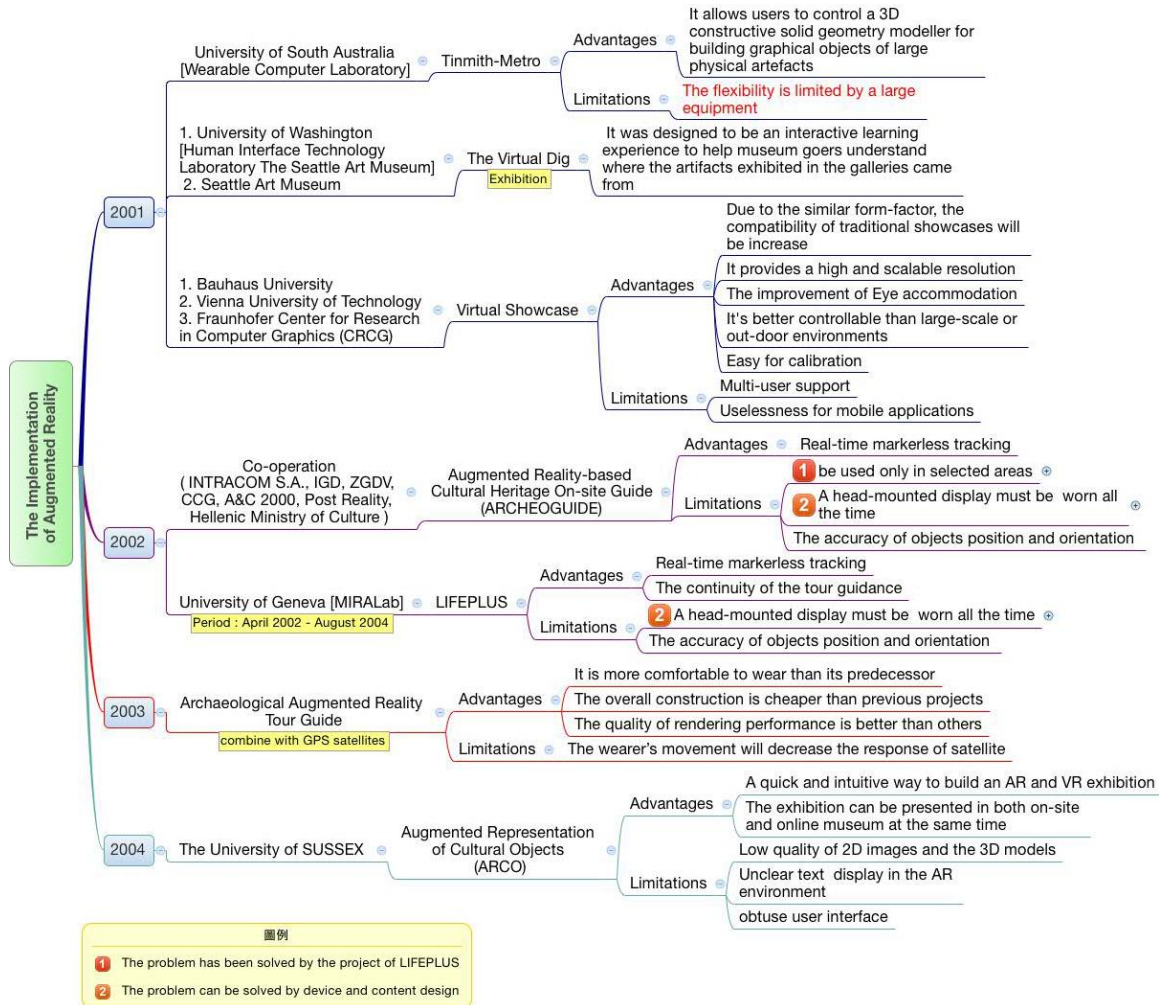


Figure 4-4 History on the development of AR from 2001 to 2004 (see Figures References).

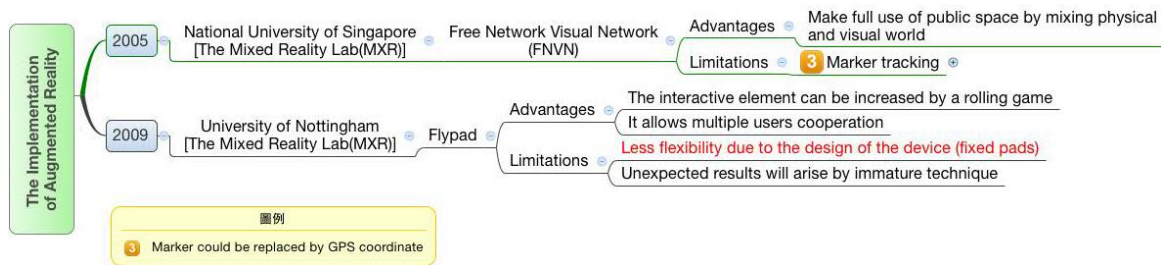


Figure 4-5 History on the development of AR after 2004 (see Figures References).

## 4.5 Repackaging

According to the statistic of Museums and Art Galleries Market Report from HighBeam Business in American, most cultural funding is decreasing across the United States in the twenty-first century. During this period of economic depression, Smithsonian, the world's largest museum and research complex in USA, has reported that 29 percent of visitors vanished in just seven months (HighBeam Business, 2012). In this period of budget tightening, the capabilities of information interchange and data repackaging are important consideration for museum digitization. The ability of data repackaging should be considered at the early design phase in the digitization process. Re-combinative collection may bring additional revenues to a museum in various ways. For example, flexible resources can increase the opportunity of art commoditization to bring additional revenue for cultural organizations, as well as to achieve the goal of marketing for attracting visitors. As the social anthropologist Mary Douglas and Baron Isherwood (1979) stated, the significance of goods is the ability to become representatives of social status, symbol or glory. With the change of economic situation, more and more collections will be converted into commercial goods in the future. The interchangeable data can reduce the production costs by reusing existing components.

The solutions of repackaging involve a number of techniques, which have been suggested over different discussions. One important consideration is migration, which allows data to move freely between different platforms for cross-platform sharing. Another vital feature is the ability of transformation, as the digital

information should facilitate easy format change for it to be recombined and reused with other items. An example is FBX, which is a file format used by the majority of 3D software such as MAYA and 3DS MAX for transferring their projects to other applications.

Although the solution of repackaging seems to have been completely defined, it has raised the issue of quality control. Giaretta (2009) suggested that the result of multiple file conversion should be paid more attention to before the information is transformed. Thus, how to ensure the converted information is identical to the original and whether the health status of the file is available for long-term preservation will be a critical topic of deliberation in the future.

## 4.6 Discussion

In this chapter we have tried to articulate a prototype framework by pointing out how some key elements can influence and improve the user experience when visiting museum. Several practical strategies and potential challenges were provided based on each element. We first compared the difference between Casual InfoVis and Traditional InfoVis in the Visualization, and pointed out how the semantic technology can implement the factors of personalization by adopting the ontology of Cidoc-CRM in museum. We also summarized the development of AR and listed several core technologies that may enrich the interaction and education factors during the appreciation of on-site collections. Final, we reinforced the importance of repacking, which can improve the intercommunication between different museums and galleries and further reduce the preservation risks. After setting up the principle of research framework, we assert that if all elements can be considered in the development of museum digitization, the visitors' experience will be enhanced.

# 5. Development of Museums Electronic Devices

## 5.1 Introduction

Last chapter established the principle of our research framework by elaborating the challenges and solutions of digital curation. In this chapter, we narrow it down to the development of digital technologies in physical venues, with particular focus on the portable electronic devices. From the previous research, Tsapatori (as cited in Peranetti, Region, Calaon, & Tricarico, 2013) indicted that the techniques of VR and AR have been piloted to enhance the exhibitions in over a quarter of European museums. Many research projects and organizations are concentrating on building their digital platform using different technologies to compensate the weaknesses of traditional on-site museums in which an invisible gap exists between visitors and collections. Examples are the Ripoll Monastery exhibition at the National Art Museum of Catalonia (Andujar, Chica, & Brunet, 2012), the virtual showcase (Bimber et al., 2003), and the research project of Augmented Representation of Cultural Objects (ARCO) (Wojciechowski et al., 2004). Previously, the display platforms were often dominated by large complex equipment such as projectors or wide screen monitors. However, with the continuous speedup of mobile hardware and their penetration rate, some major museums have turned their digital display platform from immobile desktop hardware into flexible portable devices. The Google Android and Apple iOS have therefore become the common platforms for visitors to

experience digital collections. In the following sections of this chapter, we first present the history of electronic devices in museum and gallery settings and then introduce a survey in the application of on-site electronic devices based on the asserted principle. The purpose is to provide a guideline and idea for the development of research prototype.

## 5.2 History of electronic devices in museum

With the rapid increase in user population, mobile and wearable computing devices such as widescreen smartphones, Google glasses, and smart watches are increasingly being developed as common communication interfaces for various applications. In museums and art galleries, Audioguide and Multimediaguide are the two most common solutions in which visitors are able to concentrate on the appreciation of exhibits while receiving deeper information at the same time. In the early years, most of the approaches were based on bespoke system in order to fully control the system framework, layout design as well as the content structure for each exhibit. According to Loïc and Walker (2008), Stedelijk audio guide, a closed-circuit short wave radio broadcasting system, was the first museum handheld device. It was brought in by a Dutch typographer and museum curator Willem Sandberg for a high-profile short-term exhibition named “Vermeer: Real or Fake” in Stedelijk Museum in 1952. The introduction of this approach was to provide foreign language tours to visitors during the exhibition. The device was initially introduced by Philips, a Dutch electronics company, for cinemas as a service to the hard-of-hearing. Loïc described the entire system as several functional components: a series of on-site loop-aerial, which was pre-installed into the skirting board around the outside of the galleries; a broadcast station, which was served by an analogue playback tape recorder; and a portable radio receiver, which was equipped with headphones for visitors. When visitors enter the audio-capture loop zone inside the museum, the broadcast station will transmit the audio through loop aerial to the receiver. In this early approach, all visitors will receive the same foreign language

recording broadcasted concurrently whenever visitors enter the museum, so that a PA (Public Address system) was required to broadcast the start of each record. In terms of the novel experience this service provided, it redefined the visitor's relationship with the museum.

Moving to the early nineties, with the constant improvement of technology, the museum device has changed from a simple audio provider to a multi-functional media presenter. The Tate Modern museum was one of the early examples, which provided a multimedia tour called The Tate Modern Multimedia Tour Pilot (MMT) for offering a wide range of digital contents by means of audio, video, and interactive application via PDA. It was sponsored by Bloomberg, a business and financial market news agency, and collaborated with Antenna Audio in 2002. The device provided a 45 minutes pre-set tour, and was associated with on-site wireless network for receiving the up-to-date information from the local server as well as detects visitor's physical location so that they no longer need to input a correspondence reference number for relevant information about collections. The initial purpose of this attempt was to observe the effectiveness between application and wireless environment in the museum, and improve the designed content by evaluating the various approaches (Proctor & Burton, 2004).

Through the decades of development in portable devices for museum and art gallery, technological obsolescence has gradually militates against the adoption of bespoke system. The close system soon revealed its weakness when authorities need to focus their attention on both hardware and contents due to the limited resources. Many organizations and curators have therefore switched their focus to smartphone devices with customized applications as part of exhibits' representation. Some well-known techniques such as VR, AR, QR Code, and html5 have soon been used widely to improve the capability of mobile applications (Ceipidor et al., 2013). However, according to the survey of Museums & Mobile in 2013, most of the mobile-based museum apps are developed to be an information provider without back-end supports. The functions of pre-recorded audio tour remain the most



common feature, which offers extra information related to the exhibits and collections by associating with building plans and pre-loading videos (Loic Tallon, 2013). Typical examples are the virtual museum of the Louvre on iPhone (LeVitus, 2010), the State Hermitage Museum in Saint Petersburg, and the Love Lace exhibit in the Sydney Powerhouse Museum (Weiner, 2011).

Despite the majority of museums and art galleries applications emphasizing the capability of information feeding, few projects place emphasis on the visitor-based interaction with limited degree of personalization. An example is the Solar Equation, a large-scale public art installation, which was a part of the 2010 Light in Winter Festival in Melbourne Federation Square. According to Lynch (2011), this art presentation is a result of a faithful simulation of the Sun, 100 million times smaller than the real thing. Through the pre-downloaded application on iOS devices, visitors are able to interact with the installation by disturbing the animations on the reflected surface in real-time, and select different visualizations instead. Based on the changes of surface animation, this attempt has implemented the practical interaction between participators and collections.

Another example is StreetMuseum, an outdoors AR mobile app launched by the Museum of London (Hoare & Sorensen, 2012). With this application, visitors can experience the city appearance by manipulating historical images in AR environment via their iPhone screen in over 200 sites of London City. The motivation of this app was to bring the museum's photographic collections and artefacts alive by look through their mobile screen and see how the past emerges. Similarly, the American Museum of Natural History presented a mobile AR tool specifically designed for one of the exhibitions called Beyond Planet Earth: The Future of Space Exploration. The application allows visitors to detect 11 AR markers throughout the museum, and mark their favourite collections before share their opinions and experiences with others via social network (BRUSTEIN, 2011). In this approach, limited personalization and interaction have been addressed.

## 5.3 Usage of on-site electronic devices

From the development trend discussed above, handheld devices such as Audioguide and Multimediaguide have been used by the museum sector to enhance visitor's experiences. However, over the past ten years, since smartphone has embraced people's life, the application of such devices in museums and galleries has changed unprecedentedly. Many organizations have turned traditional bespoke system into smartphone-based application (APP) in order to increase the investment in visitors' experience, while reducing the threshold of hardware maintenance. According to a recent survey conducted by Tallon (2013), over 70% of art museums have provided mobile experience to engage visitors, in comparison with 2012, only around 50% of organizations reported its usage. He explained that due to the affordable cost, smaller institutes are now much more willing to adopt mobile technology more than ever before. However, from the visitor's and investor's viewpoints, the issue of whether the applications have reached their common expectation has frequently generated a great deal of heated debate. Concerns such as will the application truly enhance the visitors' experience, or what kinds of aspects should be involved in the design stage, have become very relevant with regard to the development of mobile technology in the field. In this study, we clarify this trend by assessing existing development of museum mobile applications from different perspectives.

In the last chapter we have identified different strategies needed in the framework for the enhancement of visitors' on-site experience. The aspects of Visualization, Personalization, Interaction, Education, and Repacking have been identified as five key strategies in the museum digitization (Li and Liew 2014). Here, we adopt these strategies as the criteria to analyse the achievement of visitors' experience in museum mobile applications by investigating the world top 100 most visited museums. The purpose is to understand the effectiveness of mobile settings in these iconic organizations, and discover the weakness of current implementations for further improvement.

### 5.3.1 Samples and Data Collection

Carefully selecting the samples would increase the representativeness of the result significantly. The sampling of this survey is based on the list of “Top 100 Art Museum Attendance 2012” which was published as a special report by the Art Newspaper in the April of 2013 (Paulo, Pes, & Sharpe, 2013). The publisher is a London based monthly art newspaper established in 1983, and this special report is released annually with the aim of providing the visitor numbers in art museums and exhibitions, and centres that organizing temporary art displays for the last financial year. It has become one of the most influential and widely observed international rankings since its first release in 2012. Although the list includes most major organizations around the world, some well know museums such as Forbidden City, National Anthropology Museum in Mexico, and Museo del Prado were excluded due to the classification of historical monument. According to Xinhua news agency (Yi, 2014), Forbidden City has attracted more than 14 million visitors annually and is the most visited museum in the world. Miguel Leon Portilla, a Mexican anthropologist and historian also mentioned in an interview held by The Latin American Herald Tribune that the National Anthropology Museum receives between 1.3 and 2.3 million visitors per year (“Anthropology Museum Marks 50 Years Showing Mexico’s Richness to the World,” 2014). Meanwhile, Museo del Prado reported that its visitor numbers has gradually increased from 2.1 million in 2006 to 2.8 million in 2012 (Museo del Prado, 2013). Therefore, in order to comprehensively understand the circumstance of the development in museum portable devices, we include these cultural monuments in our samples.

For data collection, three stages of data collection are used to assemble information: online search, personal contact, and personal visit. In this survey, the data are mainly collected from online resources except the cultural organizations located within Australia, Taiwan, Japan, and South Korea, which they are personally visited. The resources from Apple iTunes app store, Google Android market (Google Play), official online websites and discussion forums, and official annual reports are

considered in the first stage of data collection. For the second stage of data collection where no online information is available, the institutions are contacted over phone calls with their media/user experience department or by emails and social media such as Facebook or twitter. In the third stage, the chosen museums that are located in countries listed above are inspected personally. The purpose of these collection methods is to ensure that robust information can be obtained coherently for the next step of evaluation.

### 5.3.2 Evaluation criteria

In order to limit the influence of on-site electronic devices to the individual visitors, and reduce the variability of the results, four evaluation criteria are defined prior to the survey: Applicability, Pertinence, Validity, and Precision.

1. **Applicability** - The resources must be applied to the entire museum on a permanent basis. Due to the limited range of influence and limited period of applicability, the devices or applications that are designed for specific exhibits are excluded except if the museum display is consisted of a large number of temporary exhibits, for example, the Centre Pompidou in France.
2. **Pertinence** - For the indicators of on-site interaction, the applications that cannot be used on-site such as the ARMOURY CHAMBER ELECTRONIC GUIDE at The Moscow Kremlin ("Armoury Chamber Electonic Guide, Moscow Kremlin," n.d.) are not considered. For the indicators of personalization, the survey only evaluates the resources that are available for personal use. The applications such as on-site installations or group-broadcasting system are excluded.
3. **Validity** – In consideration of the timeliness and accuracy of information, the resources need to be authorized by the official organizations or cooperative

publishers. Private approaches such as the apps for Acropolis and Museum Audio Guide provided by AMFINOMI for Acropolis Museum in Greece are not included.

4. **Precision** – In order to reduce repetition, the resources that provide identical functions for the same venue are not included.

Although we have listed five strategies that determine the achievement of users' experience in previous chapter, the aspects of Repacking are excluded from this survey due to its different focus. The strategies of Visualization, Personalization, Interaction, and Education are judged primarily relevant to the visitor's experience, whereas Repacking is primarily relevant to the authorities such as curator or manager.

### 5.3.3 Results and evaluation

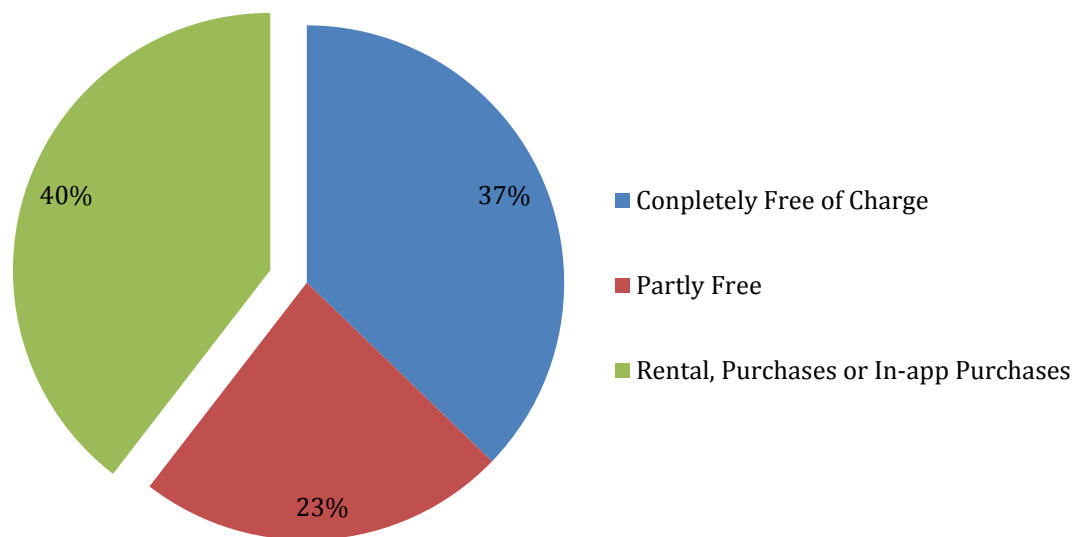


Figure 5-1 Cost of electronic devices in museums.

After setting up the criteria and constraint, the first and second steps of data collection was done in March to May of 2014, and the third step of personal

inspections was spread through the year. Appendix1 shows the final result of data collection. There are a total of 103 organizations located in over 23 countries. Most of them are located in Europe (52%), the United States, and Canada (18%). The results show that the majority of museums surveyed are available to engage with on-site visitors by Audioguides or Multimediaguides/smartphone apps. Among them, 35 organizations support both engagements, 23 provide Audioguides, and 28 provide Multimediaguides or smartphone apps. Only 17 organizations do not offer any in-store handheld electronic device. Some interesting implementations were explored during this year-long survey. For example, the interactive platform of Musée du Louvre is operated by a Nintendo 3DS, the support of ScopifyROM<sup>6</sup> technology in the Royal Ontario Museum allows visitors to see X-rays of an Egyptian mummy's coffin from their own device and load a decoder to translate the hieroglyphs on the outside, and National Gallery of Ireland adopts Vision Recognition technologies<sup>7</sup> to replace the function of traditional Audioguide. With these state of art technologies, visitors' on-site experiences can be boosted dramatically. However, as shown on Figure 5-1, although the authorities attempt to enhance museum experience via mobile devices, 40 percent of services charge extra fee from the admission in either on-site renting, or online/In-app purchase; only one third of organizations offer the experiences completely free of charge.

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<sup>6</sup> ScopifyROM is an app-based application that provides a new interactive way to explore museum objects. Through QR scanning over the museum, the application can drive visitors into the artefact deeply by presenting text, video, audio and interactive graphics.

<sup>7</sup> The Vision Recognition technologies called Vstory image recognition technology is an inter-platforms smartphone based Audioguide developed by Espro Acoustiguide Group. Instead of typing numbers on the keypad, this application adopts device camera with image recognition technology to detect collections.

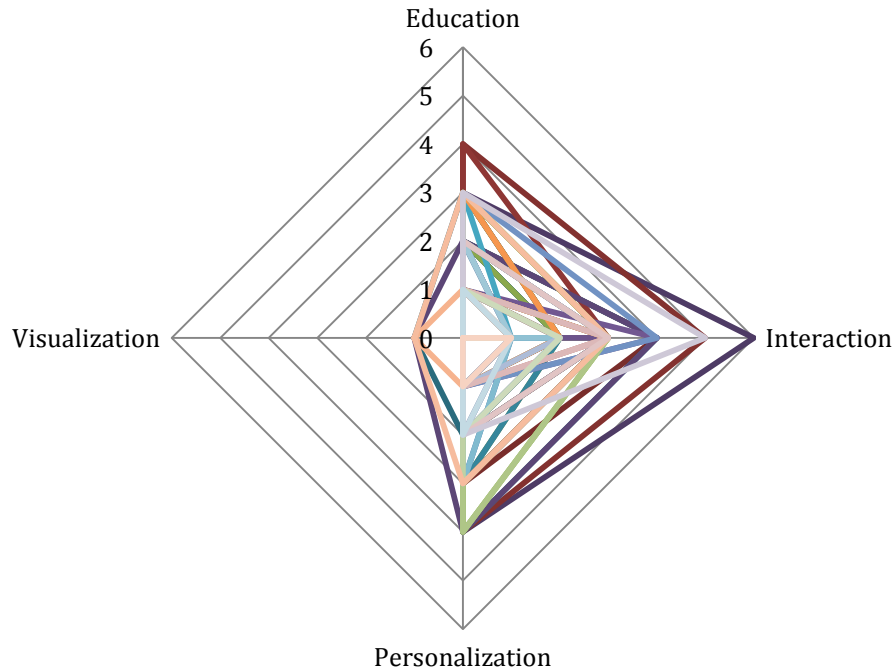


Figure 5-2 Number of functions that are provided on-site to enhance visitor experiences.

Regarding different digital strategies, Figure 5-2 indicates that most respondents concern more about visitor interaction than other aspects. According to our survey, British Museum provides up to 6 interactive functions in its smartphone app including audio guide, outdoor navigation, on-site floor maps, 3D model interaction, social interaction, and 2D virtual environment presentation, and is the most interactive application. These passive interactions allow visitors to communication between physical environment and collections. On the other hand, the aspect of Visualization appears to be a major weakness in the development of museum handheld devices. Also, only 3 out of 103 organizations support after-visit feedback such as trip overview or a list of the visited collections. None of them provides initiative information or recommendation during the appreciation. Interestingly, even for the organizations that offer after-visit experience, many of these feedbacks can only be received by email. It means that visitors are unable to obtain the feedback directly when they are still on-site.

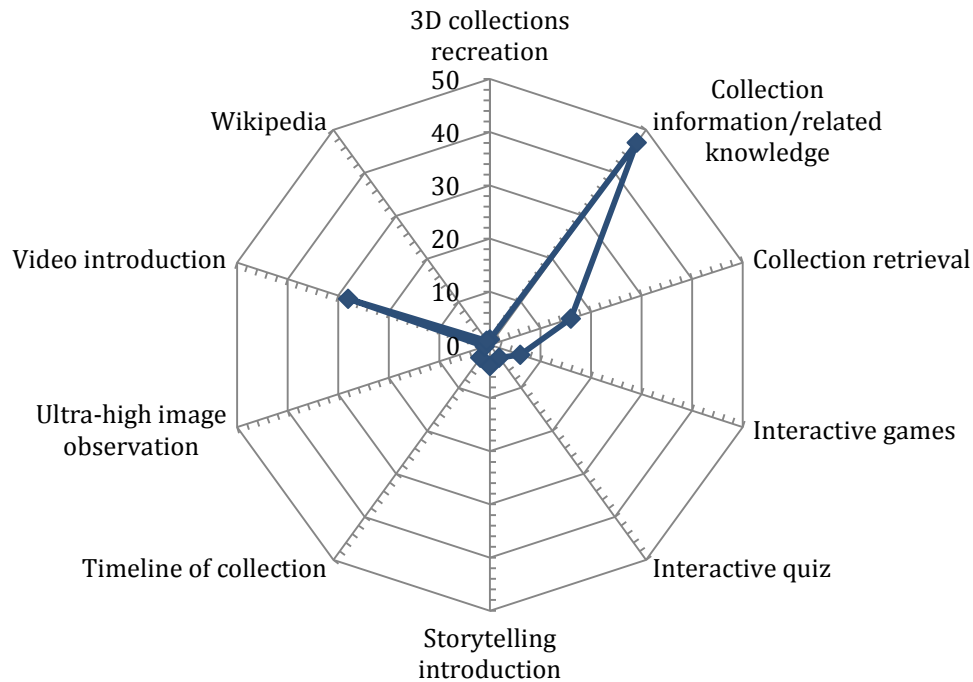


Figure 5-3 Distribution of adopted functions in the education aspect.

From Figures 5-3 to 5-6, we display in detail the distribution of adopted functions from each aspect. As illustrated in Figure 5-3, 10 functions are offered to enhance educational experiences. It is clear that the most popular method to enhance education through technology is by providing extra collection information and the knowledge related to its background. This is followed by the video based introduction, and collection retrieval. It is worth noting that instead of literal transcription of collection information, some organizations attempt to use dynamic presentation to trigger visitors' potential learning interest. For example: The National Museum of Korea and Gyeongju National Museum present their collection knowledge with a series of storytelling videos; the literal transcriptions of antiques are replaced by 3D recreation clips in the State Hermitage Museum; and the Van Gogh Museum applies real world panoramic with audio guide to explain Vincent's painting.



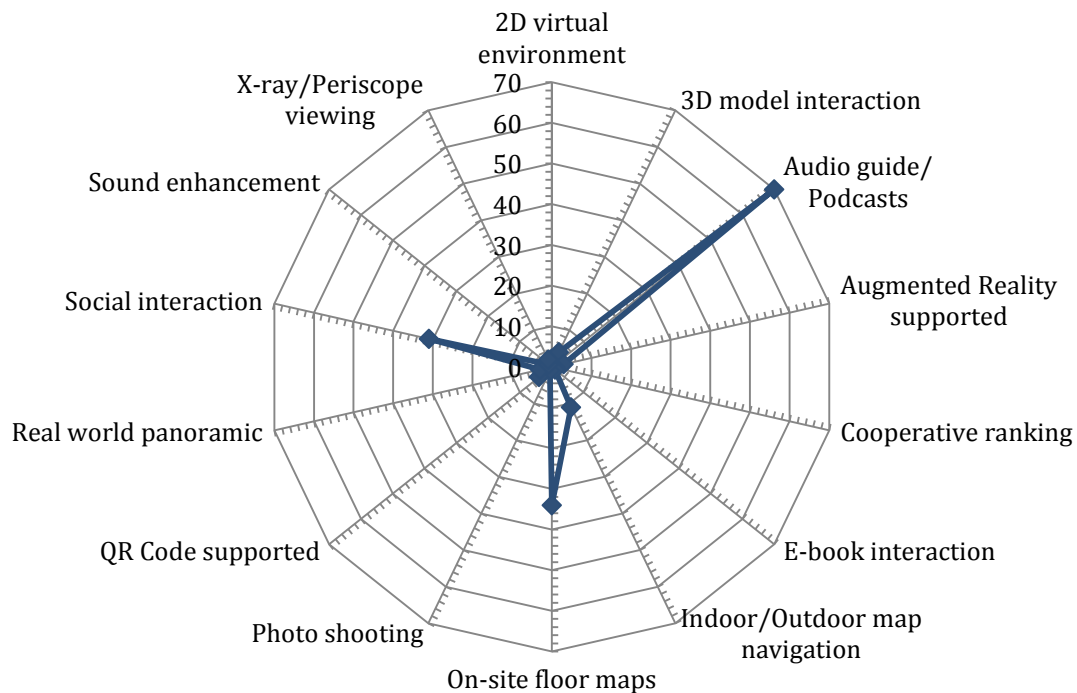


Figure 5-4 Distribution of adopted functions in interaction aspect.

Figure 5-4 indicates that interaction is the most popular objective conferred on mobile devices by museum authorities. According to the result, fourteen different approaches are deployed to reach various interactive manipulations across different platforms. By mapping these techniques related to applications in the survey, some interesting trends and facts are apparent. For example:

- The traditional pre-recorded audio guide is still the preferred technique in the vast majority of adoptions, with 70 out of 86 authorities.
- Social Medias such as Facebook or twitter gradually become the major communication platform between visitors and organizations compared to other conversation tools such as email or phone calls.
- The concept of cooperativity has not yet been accepted by museum authorities even with the rise of social media. Over 30 museums support social interaction, however, only NPM provides cooperative ranking.

- The technique of Indoor-GPS still has a long way to go with respect to precision. Although some organizations such as The Art Institute of Chicago and Museum of Contemporary Art Australia provide the function of indoor navigation for visitors to target on-site collections, none of them can be operated correctly.

Figure 5-5 and 5-6 illustrate the distributions of the remaining aspects. In comparison with other figures, Personalization is regarded as the third popular application just above Visualization. As the figures provided below indicated, some ideas are being explored. First, the current strength of personalized feature is still focusing on the language-of-delivery aspect such as multi-language audio or interface, and languages for different targets. Although multi-language audio appears popular in this survey, this is due to the common adoption of traditional Audioguide. Almost 60% of museums still provide the options of traditional Audioguide as an information provider despite significant advances of mobile technologies over the past decade. Second, the concept of machine-guided tour is implemented in some museums with strategies such as personal trajectory guide and pre-set fixed tours. Unfortunately, without the preceding procedure of user behaviour data collection and analysis, these systems can only perform preloaded tours with limited number of themes, for instance, the African tour and the Art in Bloom tour in The Art Institute of Chicago, and the era-based tours from 1500~2000 BC in the Tate Britain museum. It not only increases the work load in system maintenance as the tours need to be redesigned each time after a change of exhibits, but also reduces the personalized feature since visitors might not be interested in such pre-arranged themes.

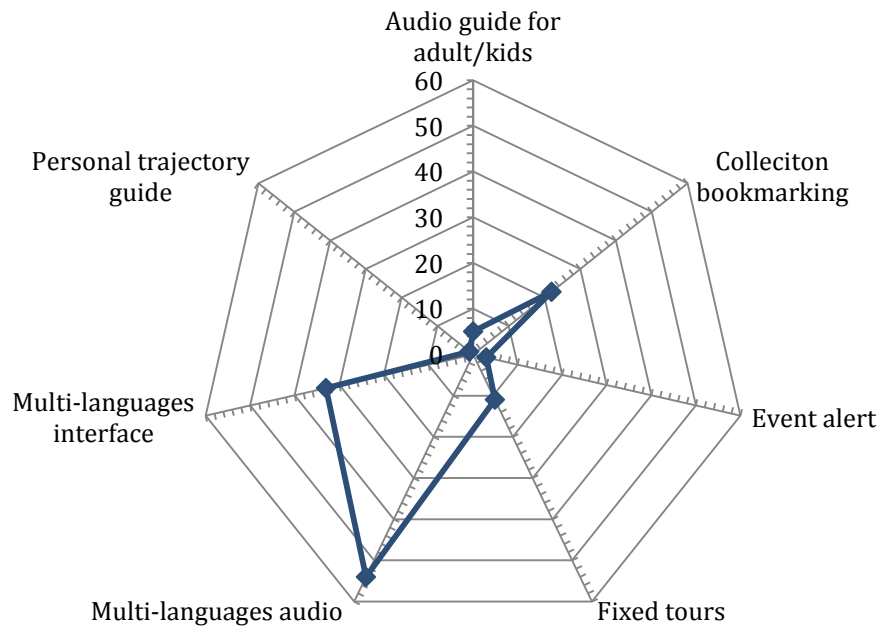


Figure 5-5 Distribution of adopted functions in personalization aspect.

With regard to Visualization, this survey attempted to observe this aspect from the adoption of Casual InfoVis concept as introduced in Section 4.2, which indicated that the ideal visual interface should be able to collect users' actions or information proactively during the interaction. However, according to the result, only one implementation is found in three museums, the Art Gallery of Ontario, the Museum of Modern Art in USA, and the Museum of Contemporary Art in Australia. These museums allow visitors to access their visited collections as a list by either marking interested collections manually or recording the collections from the participated pre-set tours.

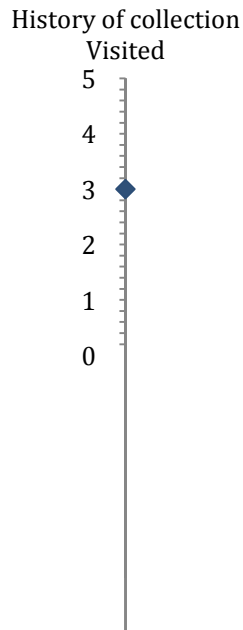


Figure 5-6 Distribution of adopted functions in visualization aspect.

## 5.4 Discussion

This chapter surveyed state-of-the-art applications and limitations related to museum electronic devices. The aim of this survey is to clarify the current trend in the development of on-site museum technology and identify the gaps that can be closed in the future. Through this comprehensive investigation, six recommendations are listed below with regard to boosting the physical museum visiting experience and restoring the role of museum and art gallery as an education institute:

1. The system should be maintained easily, applied widely, and developed based on open sources technologies on different platforms in order to reduce the cost of development and avoid extra charge for visitors.
2. The development of museum mobile device needs to pay more attention to the cooperation between Personalization and Visualization features.

3. The aspect of personalization needs to consider ways to provide interactive information or provide real time recommendations about the collections during the visit.
4. The concept of Casual InfoVis can be considered as a strategy in the system development to collect visitor's behaviours proactively.
5. Social media should be used as a cooperative platform to enhance on-site interaction.
6. The collection information should be accessed through interactive methods such as AR or QR Code to trigger visitor's interest in order to reach the educational goal.

# 6. Conceptualizing the Research Prototype

## 6.1 Introduction

Implementing a prototype for verifying the design framework and theory is one of the crucial steps in our research. In the previous chapter, we described the current development of mobile devices towards user experiences by discussing their implementations in cultural organizations. Unfortunately, most of these approaches focus little on the interactive perspective with limited passive personalization such as favourites marking. Here, we illustrate a new approach in which the personalization feature will be achieved proactively. The idea is generated based on the six recommendations obtained from the evaluation of museum mobile devices. In this chapter we conceptualize the system architecture by introducing several design principles and related technologies.

With regard to the first recommendation, one of the design principles is to adopt the concept of Service Oriented Architecture (SOA), in which each distinct component can function as an independent service to other components. The purpose is to maximize the effectiveness of system architecture while reducing development cost. By using SOA, various components are grouped into three distinct platforms; front-end interactive interface, middle data exchange platform, and back-end database. To address the second and third recommendations, the

technology of Semantic Web acts as a personal information recommender in the back-end to provide an on-site proactive personalized service and interaction. For the fourth recommendation, the concept of Casual InfoVis is adopted as the foundation of the front-end design for gathering personal interests from the visitor without complicated operations. The detail of how to apply this concept to front-end interface design will be described in chapter 8. Finally, the last two recommendations are considered by applying the dimensions from interaction design, which will be discussed in detail in the next chapter.

## 6.2 Service Oriented Architecture (SOA)

SOA, also called service-orientation is the underlying structure that connects communications between services. According to Sprott (2004), SOA is a way of building distributed computing applications which provide services for end-user or other services within the system. Under this framework, each service is treated as a self-contained unit that operated as an independent module to perform the designated tasks. In other words, depending on the service design, these discrete components can be deployed separately or reconnected seamlessly for different purposes. It not only increases the capability of the system for various applications, as the components can be added, removed or reused throughout the system, but also reduces the cost of development and ongoing maintenance.

Although there is no industrial standard related to SOA, some basic principles are applicable during system development (David Linthicum, n.d.).

1. *Distributed* – the services are able to be composed from the distributed systems on networks such as LAN or WAN, and they can be supported quickly on different platforms for various purposes.
2. *Loosely coupled* - the modules need to be loosely coupled and satisfy

principles such as *reusability, discoverability, granularity, modularity, combinability, flexibility, autonomy, interoperability, and componentized*. In this way, modules can be substituted in during system changes for improving the flexibility of the system.

3. *Open standard* - SOA focuses on standardization and interactivities between components, so common open standards should be supported during the development in order to avoid the problems of integration between different platforms.
4. *process centric* – the work processes need to be specified for separating the services to the individual modules when constructing the system, so that other developers can select appropriate elements to complete the work in accordance with the service requirement.

## 6.3 Data Collection, Integration, and Evaluation

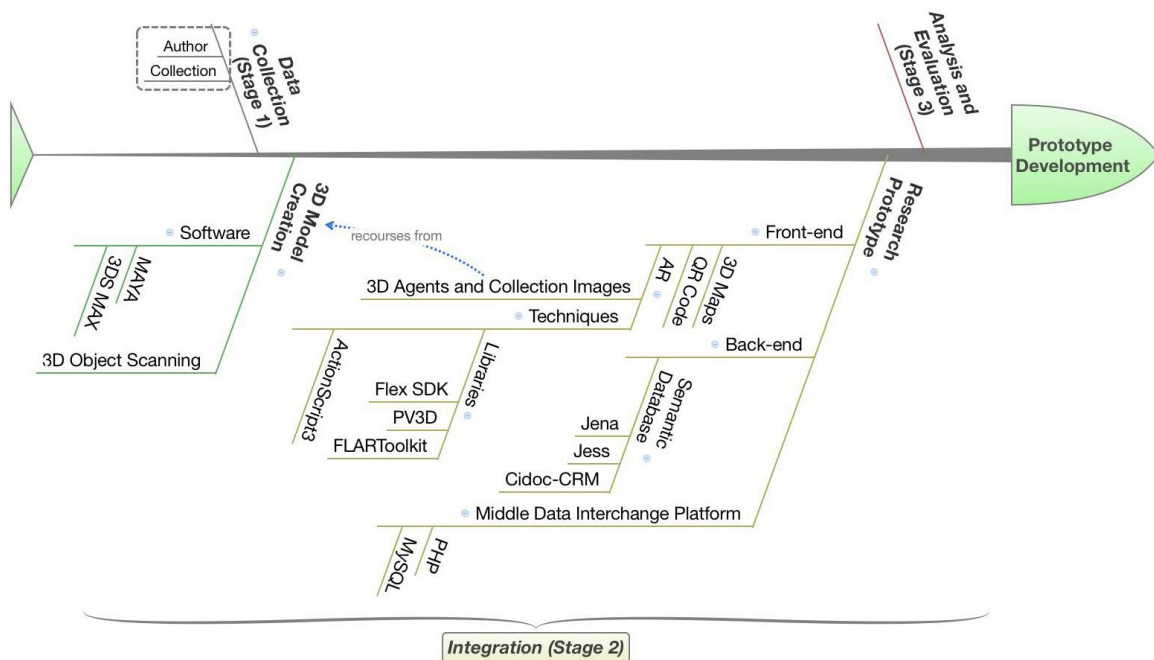


Figure 6-1 The framework of research prototype.



After confirming the design principles, three development stages are generated for the implementation of the research prototype. According to the framework illustrated in Figure 6-1, the stages of data collection will be followed by the integration phase before the final result analysis and evaluation phase. We will describe each of these steps in detailed in the following sections.

### 6.3.1 Data collection

Collecting as much information about each collection can enrich the quality of metadata and further increase the capability of personalization and recommendation features. Hence, data collection is the first and crucial stage of the prototype development. In this research, we selected 50 artworks from 32 Australian artists across different periods as our samples from the National Gallery of Australia (NGA). The field categories of these artworks are diverse, and fall into different fields such as archaeology, psychology, or chemistry based on the chronology and nature of the collections. Thus, in this step, the collected data are separated into two categories for each collection for the purpose of semantic retrieval: the data from the collection itself, and the data from the authors/creators of the collection. As shown in Table 6-1, using painting as an example, the data not only includes the basic information of the author and collection but also the relevant descriptions such as style, content description, author's history, and the relationship between different authors or collections. The purpose is to generate the tacit knowledge which may be of interest to visitors automatically, for instance, to identify all collections which have similar style or concept within the museum. In general, a visitor would find it very difficult to compare various collections between different showrooms in order to find out their similarities, and a navigation system that provides this information would be helpful. Another intention is that it can help visitors target specific aspects in a collection for closer study. A bottle, for instance, could have printed on it an image of a woman holding a book and taking a walk on the street. In this example, the keyword of this collection would be difficult to

identify for retrieval if what we want to search for is the image on the bottle rather than the information of the bottle. However, through a conceptual description, the search for a similar collection will become easier.

| <b>The Data of the Author</b> | <b>The Data of the Collection</b>        |
|-------------------------------|------------------------------------------|
| Artist Name                   | Collection/Painting Name                 |
| Artist Appellation            | Type (Painting, Sculpture...etc.)        |
| Birth Year                    | Material (Paper, Metal, Ceramics...etc.) |
| Dead Year                     | Year of Creation                         |
| Painting Style                | Birth Place                              |
| Nationally                    | Specification                            |
| Teacher / Student             | Colour                                   |
| Father / Child                | Collection/Painting Style                |
| Picture from Image Archive    | Content Description                      |
| History                       | Position (Collection/Painting in Museum) |

Table 6-1 Catalogue of the data collection in the research prototype.

### 6.3.2 System integration

The stage two is the integration of several designed components, front-end, middle platform, back-end, and 3D models. In this stage, a system architecture is provided with three procedures developed under the User-Centred Design (UCD) principle, which asserts that ‘the product should suit the user, rather than making the user suit the product’ (Courage & Baxter, 2005). In line with this statement, the purpose of our system is to collect visitor’s interest quietly using intelligent technology when they interact with the front-end. Figure 6-2 shows a flow chart for the entire system architecture. As can be seen from the chart, visitor’s interest will be captured through the interaction of front-end interface in which the functions of AR, QR Code, and 3D maps will be provided with various types of collection information for visitors to gain interactive experiences in the first step, and then in step two, the results in the form of keywords will be sent to the database via intermediate web service in which the entire personal visiting history will be recorded. When a new keyword is detected, the data retrieval process will be activated by the database, which stores the collections information using Resource

Description Framework (RDF) format. In step three, the reasoner infers the collections of interest from the input query and output a recommended collection with its location information back to the front-end. At this stage, a cycle has been completed and a new cycle will start, and a personalized tour path will therefore be established.

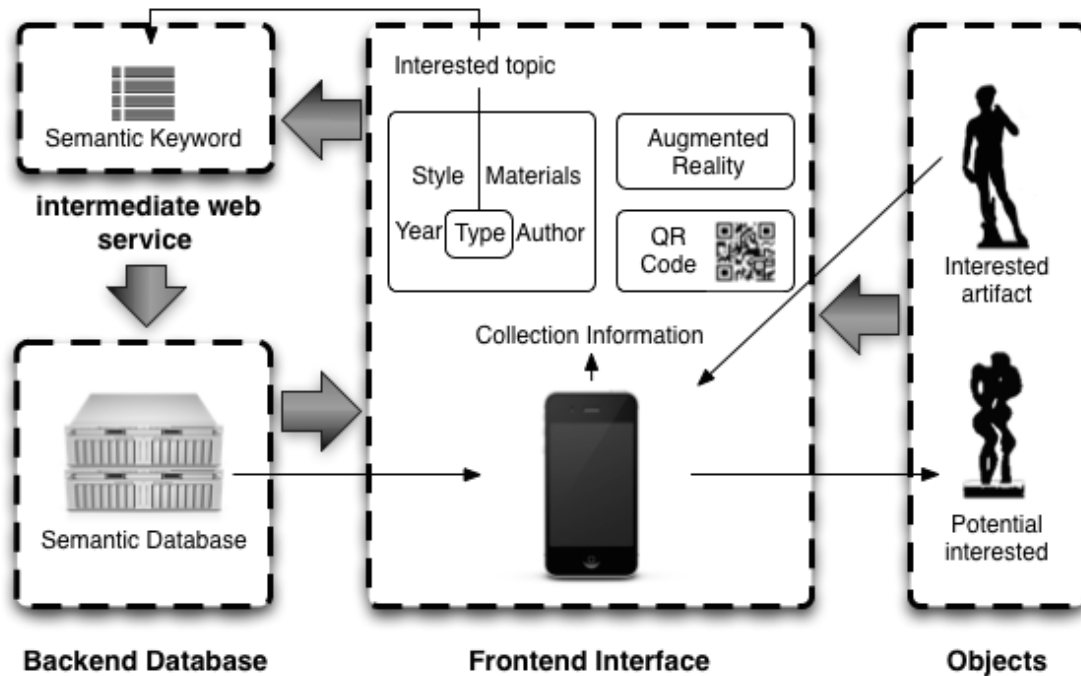


Figure 6-2 System architecture of the research prototype.

The database that we adopted in the implementation is based on the technology of Semantic Web. The role is to enhance the factors of museum personalization and recommendation system. As outlined in Figure 6-3, due to the variety of components involved in the framework of personalization, a suitable basic ontology is required for classifying the attributions of the museum collection. Currently, the Cidoc-CRM and CDWA are two ontologies that are designed to focus on the cultural heritage. In this research, we adopted Cidoc-CRM as the basic ontology to associate with RDF and other tools that are used to edit semantic information, such as Protégé (Stanford Center for Biomedical Informatics Research, 2012), Apache Jena (Carroll et al., 2004), Jess inference engine (Friedman-Hill, n.d.), or SWRL language (Horrocks,

Patel-Schneider, & Boley, 2004) for building a knowledge inference platform in the back-end. We will discuss more detail about system technical descriptions and its elements related to the asserted framework of this research in chapter 8.

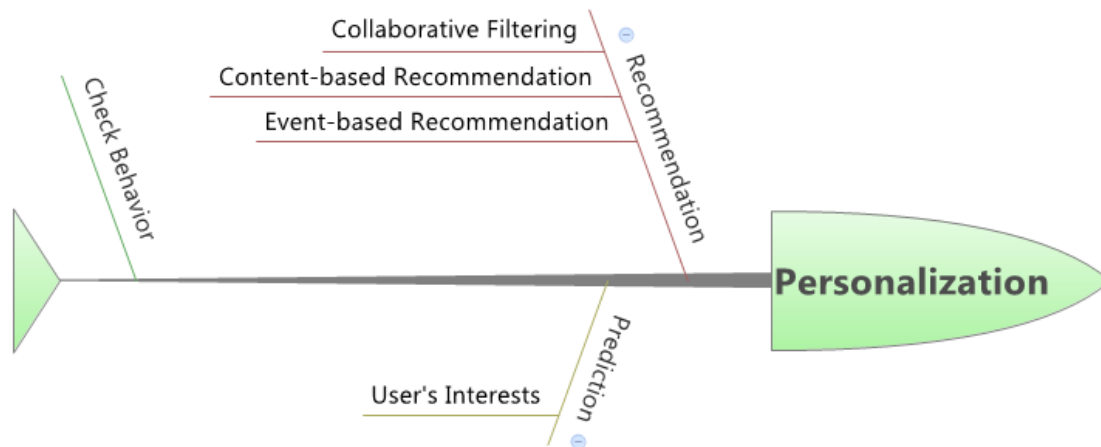


Figure 6-3 Museum personalization framework.

### 6.3.3 Evaluation

After the system integration, the prototype is then evaluated as to its effectiveness in enhancing interaction and personalization of on-site museum visit in stage 3. Several technical criteria and methodologies are used to determine the success of the system in achieving these goals. First, the system interfaces are developed based on the result of card-sorting, and evaluated by Cognitive Walkthrough (CW) which is one of the common usability inspection methods in HCI. This approach will be described in detail in chapter 9. For the personalization aspect using Semantic Web, technical metrics such as concept capturing and generation, and relevance of recommendation are evaluated. After the system usability evaluation, feedback from real users about the implemented prototype are analysed regarding its effectiveness and weakness in enhancing user experience in on-site museum visit.

## 6.4 Proposed services and expected outcome

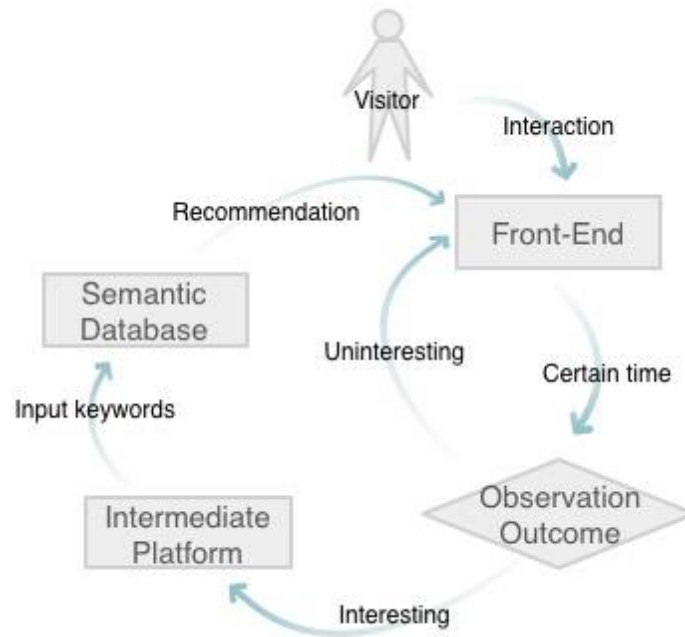


Figure 6-4 Visiting procedures.

The organization and integration of semantic input and recommendation output between front-end and back-end for providing the proactive personalization through interaction is the vital contribution and the most challenging task in this research. The goal of this attempt is to help visitors to discover their potential interest and provide extra information during their appreciation in on-site museum and art gallery. According to the flow chart of visiting procedure in Figure 6-4, the visitor's interest will be determined by the time they spend on the manipulation of each catalog group on the interface. When the duration of manipulation has reached a certain time, the system will provide an opportunity for user to tag the group that they spent most of time as an interested item, and offer more information such as the name and location of the potential collections of interest around the museum as recommendation through the semantic database. In this way, the suggested collections may have the same context such as: they are all created during the Roman Empire; be of the same series such as Sunflowers; are the subject of two

series of sculpture; of a similar style such as the Renaissance; similar material such as metal and marble; an affected style such as Ionic Order and Greek Revival; or perhaps the year of creation such as 27 BC.

Due to the variety of intention and background of people who come to a museum or art gallery, the outcome of the system has to meet the needs of different groups of people, such as casual visitors, professional visitors, curators, and administrators. For example, the casual visitors come to a museum often without professional art knowledge and may need more spiritual relaxation than wanting insight of the collections. However, the professional visitors expect further knowledge from the collections that they are interested in. Curators require wider information and suggestions concerning the specific collections for future exhibition needs, and administrators focus on the versatility of system performance and maintenance. This research identifies the diverse needs of different kind of visitors and finds ways to organize information to meet their needs.

# 7.Spatial Approaches to Interaction Design

## 7.1 Introduction

In the last chapter we introduced a conceptual framework for the development of a research prototype. The goal is to create a user-friendly interactive platform in which personal recommendations and suggestions can be provided proactively based on each individual's interest. Several design principles and notions have been considered for the system implementation from the previous discussions such as SOA, Casual InfoVis, and Interaction Design (IxD). In this chapter, we will focus deeply on the aspect of IxD with emphasis on the relationship between space and human activities. This concept will lead the research as one of the main design principles for implementing the prototype. We will first give an overview of this term, and discuss some of the disciplines that will be involved in the development of our research prototype. Then, we will discuss and criticize the existing dimensions of the literature by highlighting the issues between users' reaction and time interval that may improve the personalization factor within the current IxD structure. Although previous studies of IxD does not concern with user personalization, an in-depth inspection and analysis of existing works from different aspects could spark new insights.

The focus of this research is specifically on structuring a standard strategy of

on-site technological system that can be physically aligned with real spaces, providing visitors with an interactive and personalized solution for triggering learning based on analysing their reactive behaviours. We argue that if the dimensions of IxD that are proposed in previous research can be used appropriately and effectively, the personalized feature of museum digitization will be enhanced during a series of on-site interaction. Therefore, it is necessary to investigate how this relationship has been analysed and designed for, and what conceptual underpinnings have guided the past research.

This chapter is not an attempt to cover the entire topics of IxD. Several disciplines and examples such as Industrial Design, Architecture, Ergonomics, and Graphic Design will not be discussed. Instead, by merging IxD structure into the system implementation, this research attempts to discover how this structure can be refined into effective and diverse ways.

## 7.2 Disciplines of Interaction Design (IxD)

IxD is a frequent discussion topic in the field of Human-Computer Interaction (HCI). Lowgren (2014) defined that this is all "about shaping digital things for people's use". It was described as "Soft-face" in the first half of the eighties by its assertors Bill Moggridge and Bill Verplank who strived to create an imaginative and attractive solution to the virtual world. The initial idea was to highlight the importance between physical and digital, and endue a product or service with aesthetic pleasure for increasing the lasting satisfaction and enjoyment (Moggridge, 2007b). Following this idea, several disciplines with respective principles have been developed in both academics and industries through the past decades, such as the physical form, colour, and aesthetics in Industrial Design, the anthropometry, biomechanics, kinesiology, physiology, and psychology in Ergonomics, and the needs, motivations, and behaviour in Design Research (Interactiondesign.com.au, 2011). In this chapter, we will cover the principles related to human reaction and sensation



from another three disciplines, namely Cognitive Psychology, User Interface, and HCI. The purpose is to narrow down the focus of proposed services of the prototype, and develop an interactive front-end interface based on the users' behaviours.

### 7.2.1 Cognitive psychology

Cognitive Psychology can be regarded as the ground rule of IxD. It is the study of mental processes that affect human behaviour. According to the book of "The Design of Everyday Things" published by Donald Norman (1990), this study has led to several aspects from the design view point, which include *mental models, mapping, interface metaphors, and affordances*<sup>8</sup>. These aspects are affecting our user experience in many ways in our daily life. For example, the Apple desktop interface is one of the most successful instances that practices the interface metaphors on computer device (*Apple Human Interface Guidelines: The Apple Desktop Interface*, 1987). In this research, we endeavour to pursue these aspects into our prototype development to achieve the maximum value in museum visiting experience within limited screen space provided by the mobile device.

To achieve the above goal, the mental model will play the role of defining the potential user groups of the system. The purpose is to optimize the intuitive perception about their acts when they are visiting museums. The detail of selected groups will be elaborated when the prototype undergoes the second round of usability test in chapter 9 in which the aspects of cognitive mapping is implemented. The mapping will start off by designing the front-end UI layout using card-sorting technique, and followed by the inspection methods of Cognitive Walkthrough (CW). The interface metaphors in this research are concerned with the colour influence,

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<sup>8</sup> According to the Norman(1990), affordances is a "relationship between the properties of an object and the capabilities of the agent that determine just how the object could possibly be used" (p.11).

which will be discussed later in the disciplines of user interface. This aspect will be represented on the theme pages of each collection in the front-end and the operation interface of the back-end for enduing the diversification of metaphors into museum and gallery collections as well as building a user-friendly system interface that may increase the efficiency of collection management. Finally, the affordances will be reflected on the selected equipment that will merge the relation between spatial environment, museum collections, and on-site visitors for gaining a better museum experience.

### **7.2.2 User interface – colour psychology**

As mentioned in the last section, the discipline of user interface in this research is mainly correlated with colour psychology which connects the interface between colour and environmental stimuli. It is a meaningful constant that can send a positive or negative message according to the designed purposes, such as promoting sales, extending the time of appreciation, and even enhancing the memory of collections that have been inspected during the visiting. Frey, Honey, and König (2008) have discovered in their experiment that it is difficult for human brain to process all visual information without any assistance of colour factor. Hence, in this research, we will take full advantages of colour influence in the user interface design to dissemble the shortage of information provided by spatial on-site environment. We believe that by manipulating the brightness, contrast, tincture, light, and shade of object elements on the interfaces, one may raise the awareness of the usage of technology in museum and art gallery visits, and further boost the acquisition of aesthetic knowledge.

### **7.2.3 Human–Computer Interaction (HCI)**

The third discipline that covers this research is the theory of HCI, which has been used extensively in the industrial and commercial areas since the first

graphical user interface<sup>9</sup> was introduced in Stanford Research Centre (SRI) by Douglas Engelbart in the late 1960s. He defined HCI as a study of the interaction between users and system, with the goal of improving the machines accessibility to meet users' needs (Myers, 1998). Depending on the disciplinary scopes, HCI is sometime referred to as Human–Machine Interaction (HMI), Man–Machine Interaction (MMI), or Computer–Human Interaction (CHI). In IxD, this aspect is often conducted with several evaluations, interviews, surveys, testing, or group activities. The intention is to understand the range of ease of use when interacting with an interface.

According to Moggridge (2007a), a well design interface should be able to complete the tasks within the application framework by interacting with their users smoothly without any misleading action. In order to reach this goal, some models of interaction are usually applied when developing machine interface. One of the most famous structure is the Norman model, which defines several design stages including *user establishes the goal, formulates intention, specifies action at interface, executes action, and perceives, interprets, evaluates system state* to assess the goals of the interface. However, from the development view point, this model only concerns the interaction from users' view of interface. The communication between the system and the interface is ignored. To resolve this issue, Abowd and Beale extended Norman's model with four transformations between interactions: *Articulation, Presentation, Performance, and Observation* (Dix, Finley, Abowd, & Beale, 1998). This extension defines input (Articulation and Presentation) and output (Performance and Observation) of data to cover the communication between system components. In this research, we will pursue these features throughout the prototype development to ensure the usability quality. The purpose is to track the system responds with the aim of refining the museum visiting experiences.

---

<sup>9</sup> Graphical user interface (GUI) is the type of interface presentation that users are able to interact with computers or electronic devices using graphical icons instead of text-based instructions. The first commercial implementation of GUI is Alto, which was developed by Xerox in 1973 (Kusiolek, 2012).

## 7.3 Five dimensions of interaction design

Wide ranges of studies have been done to cover the concept of dimensions in IxD, from concrete to abstract and plane to ultra-dimension. Gillian Cramptom Smith, in the book of *Designing Interaction*, proposed four dimensions in accordance with the order of matrices: 1-D includes words and poetry, which is the fundamental core of interaction; 2-D includes two dimensional presentations such as painting, typography, diagrams, and icons, which is the extension of the first dimension; 3-D includes physical and sculptural forms that correlate to the actual space; and 4-D includes the contents that change over time such as sound, film, and animation (Moggridge, 2007a). These matrices were illustrated on a range of applications until the fifth dimension was added by Kevin Silver (2007) who endues an interaction with definitions, and refines each matrix with a language. He affirmed that, with the implication of intangible elements, the dimensions of IxD could be classified into 1-D (Words), 2-D (Visual Representations), 3-D (Physical objects or space), 4-D (Time), and 5-D (Behaviour). The first three dimensions are regarded as enable interactions, which delegate the tangible shapes of presentations, while the Time and Behaviour converge on these tangible representations to define interaction by reflecting the communications from interactive targets. Thus, in IxD, these two dimensions can be treated as an invisible channel between action/operation and reaction/presentation.

From above explanations we can understand that the last two dimensions are the main keys that reflect the effectiveness of the user experience. The Time here can be expanded as what to interact (using massive digital media), while the Behaviour can be treated as how they interact (setting proper actions and receiving expected reactions). However, according to the analysis of deployed interactive functions in the usage of on-site electronic devices presented in section 5.3, the Time is often defined to be a feeder rather than a communicator during interactive development, as the majority of functions provide only one-way of passive interaction. It means that the users are required to follow a pre-set procedure for receiving given information. For example, typing numbers on the keypad to receive

the corresponding introduction, or manipulating 3D models to see the different angles of virtual object. If they stop to execute the action, the interaction will then be interrupted. In this way, the Behaviour will therefore be influenced by paused actions and incomplete presentations or reactions.

Besides the above shortcomings, these definitions also raise another issue that the information provided by the designed procedures might not match users' interest. It could lead to the result of losing the motivation of communication during interaction. The reason of this disputation is because the IxD dimensions do not concern about other essential factors that we asserted in chapter 4, such as personalization. To resolve this issue, we argue that this limitation could be overcome by redesigning the dimensions of Behaviour. We suggest that a proper recommendation or feedback should be provided after action and operation to ensure that the reaction and presentation can be made according to the intuitive behaviour. Based on this suggestion, the contribution we are making in this area of study is that if the Behaviour dimension can be defined appropriately during the design stage, the Time dimension can have an opportunity to provide two-way feedback to achieve the purpose of personalization. In this way, the relationship between user and physical environment will be enhanced, resulting in more effective systems.

# 8. Development of a “Personal Trajectory Tracing Assistance”

## 8.1 Introduction

After setting up the conceptual framework and design principles, this chapter introduces a proposed approach called Personal Trajectory Tracing Assistance (PETTA) in which the on-site museum experience will be enhanced proactively. By incorporating the theoretical framework from our early discussions, this prototype could be used to validate the research hypotheses and answer the research questions that were raised at the start of this study.

According to the latest survey from the research firm IDC (2013), Apple's iOS is the second most common operating system next to Android. However, in the evaluation of museum mobile phone apps from Economou and Meintani (2011), most museum apps are designed exclusively for Apple devices. Therefore, in consideration of universality in the museum and art gallery communities, and the seamless integration between hardware and software, our prototype is designed based on iOS system with several major components: a friendly user interface (UI) with Quick Response (QR) code reader, which provides extensive information about the collections to enrich visitor's experience; an AR narrator, which plays an interactive role between visitors and collections; an intermediate platform which stores visiting history and establish connections between front-end and back-end;

and a semantic database which stores collection's data and making personalized recommendation during a visit.

In this research, we attempt to enhance museum experience using digital mobile devices. The goal is to extend the time of artefact appreciation by enhancing the facets of education, interaction and personalization. If on-site museum experiences can be enhanced by digital technologies, the development of digital curation in cultural expression will not only promote the roles of museums in the digital era but also boost the value of cultural heritage more than ever before. Clearly leveraging the factors of UI design and database structure can offer a valuable approach to assist curators and developers in structuring a useful digitization framework and sharing the information across the organizations.

## 8.2 System development

The prototype is designed and developed based on the existing technologies such as an iOS UI mobile interface front-end written in Objective-c for visitors to interact with the collections during their visit, a web based intermediate platform built using PHP-MYSQL for data communication between the front-end and back-end, and a back-end collections recommendation database developed using Apache Jena<sup>10</sup> and Jess<sup>11</sup> that provides collection inference after receiving the metadata from the front-end. The purpose is to demonstrate a design of the UI interface for a series of Australian paintings in NGA, and illustrates a framework showing how the visitors' behaviour can be detected by interacting with the designed interface, and thereby offering a feedback of recommendation for establishing a personalized visit trajectory.

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<sup>10</sup> Apache Jena is a free and open source Java framework that stores collections' information using semantic technology.

<sup>11</sup> Jess is a semantic rule engine written in Java language, which infers the output as visitor recommendations.

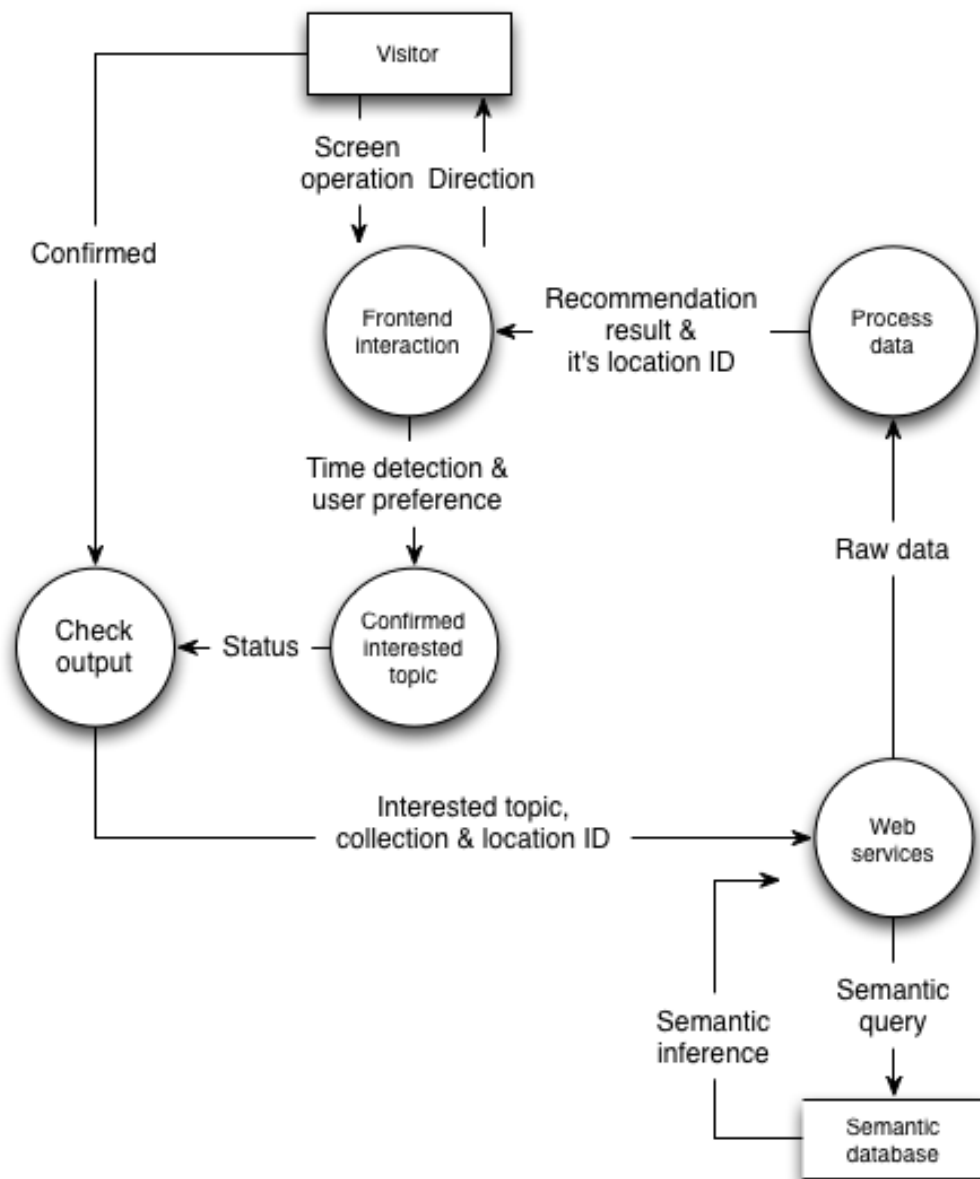


Figure 8-1 Data flow diagram of PETTA.

Figure 8-1 shows how data flows through the system. The output data is generated by the user interacting with the front-end, which is proceeded by screen touch operations. By comparing the time that they spent on each topic on the device, the system attempts to detect the user preference to determine the potential topic of interest. If the targeted topic is confirmed, the topic's keyword and current collection ID with its location ID will be transmitted to the intermediate web services, otherwise, the system will return to the detect mode and suggest user to



spend more time on the front-end interaction for preference detection. When the data flows into the web database, the collection ID will be recorded for further reference before being sent to the semantic database. After receiving the output data from the front-end, the semantic inference engine produces the recommended collection ID with its location ID and returns it to the intermediate platform. In this stage, the new ID of the collection will be recorded again before the new data is sent back to the front-end. In the following sections, we will classify the system techniques based on the different key facets that we have mentioned in chapter 4. The purpose is to present each role that technology plays within the system for understanding the effectiveness of the key factors.

## 8.3 Visualization

The visualization aspect of this implementation is mainly based on the concept of Casual InfoVis in the front-end UI layout, which was first developed using card-sorting technique<sup>12</sup>. It was used to gather the content with an appropriate navigation system and to arrange the screens in such a way where users would be most comfortable and be able to understand it easily. In other word, the goal of this process is to discover an effective, efficient, and satisfactory layout arrangement for the end users.

---

<sup>12</sup> Card sorting is one of the techniques used in the user experience design. Instead of real coding, this technique is proceeded by the number of paper cards with a group of users at the beginning of the system development to ensure the fluency of navigation paths.

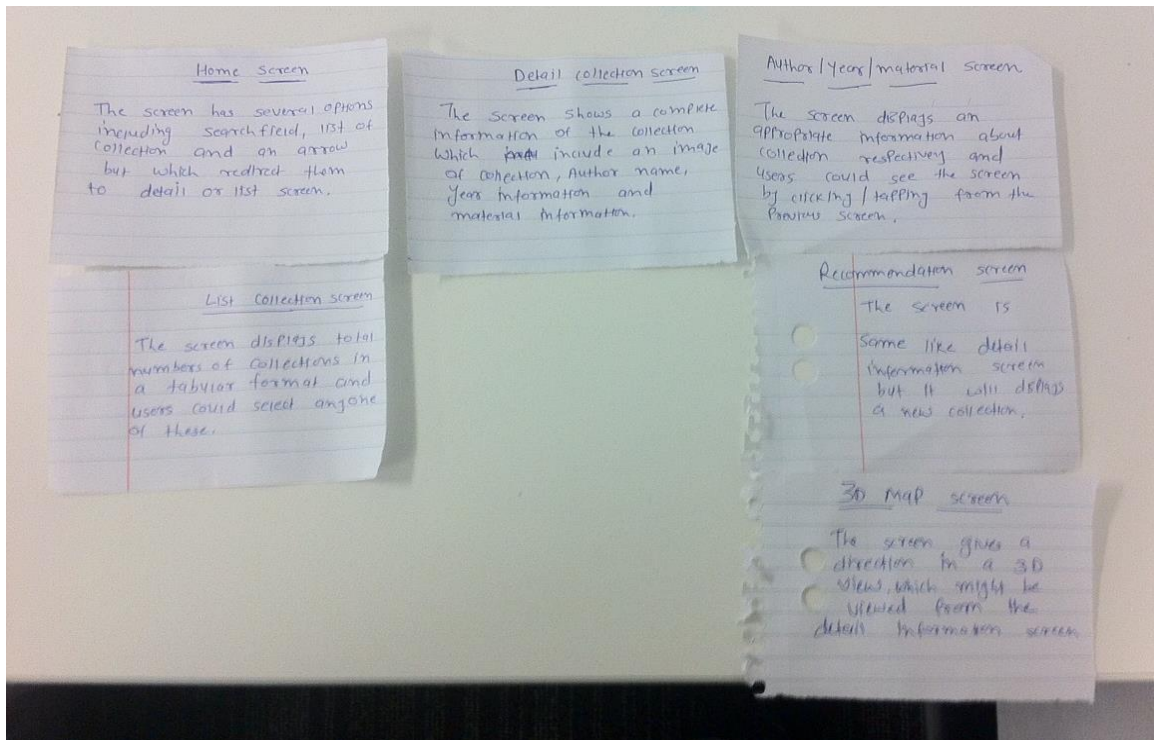


Figure 8-2 Card-sorting technique used during the system development.

The entire procedure was performed by five users who arranged several screens (papers) for different possibilities. Figure 8-2 shows the most popular arrangement from three users. Based on this result, the system provides a maximum of three layers with two entry layouts at the first layer for the initial engagement: a visit starts from the very first collection near the entrance, or a visit starts by selecting the interested collection from a collection list (Fig.8-4 B, C). As illustrated in Figure 8-3, these entry layouts provide a simple intuitive visual for visitors to pursue the system. The second layer is the main page of each collection, which contains a collection thumbnail to distinguish the current target, a node button to engage the recommendation system, an AR trigger to evoke virtual agents if applicable, and a detail information pool to bridge the next layer. The third layer is the knowledge and function layer which stores all the information about the collection into several layouts such as Author, Year, Material, and Style, and several functions that will assist the visitor during the on-site navigation such as AR, QR Code reader, and 3D Maps.

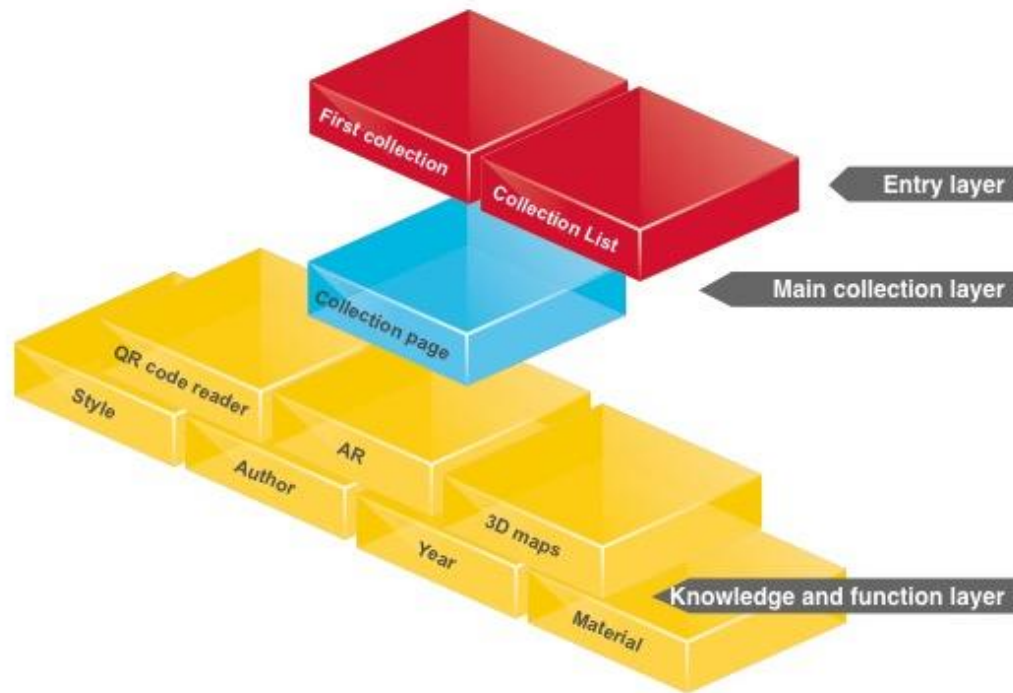


Figure 8-3 The PETTA front-end interface layouts.

After performing the card-sorting technique, several real user scenarios are set up for ensuring the usefulness of the designed layouts. In this research, two usability tests are applied before and after the prototype development. Table 8-1 displays the first round of test with two scenarios that were carried out before the actual development. The task of test at this stage is about the operational logic of the front-end interface rather than the performance of the entire system, which will be tested and evaluated in the second round of usability tests after the development described in the next chapter.

| Scenario 1 (looking for the specific information) |                                                                                                                                                                                                                                                   |
|---------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Scenario</b>                                   | You are a person who is passionate about the art and museum collections and recently relocated to the country from overseas. You know about Brett Whitley well and would like to visit his works in person in the National Gallery of Australian. |
| <b>Screen</b>                                     | <b>Home Screen</b> -Users enter the name in the search field.                                                                                                                                                                                     |

|                     |                                                                                                                                                                                                                                                                                                                                                                                                 |
|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Descriptions</b> | <p><b>Details Information Screen</b> – Users could see an image of the collection in the background and related information about current collection.</p> <p><b>Author Information Screen</b> – Users click on the author name to read more about him/her from the previous screen and they will be able to see an image of the author at the background and his work and life information.</p> |
| <b>Response</b>     | <b>Positive</b>                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Result</b>       | While participants have no experience with the system, the search function on the home screen can help them to target the information directly by typing the name of author on the search field. It provides a path way for participants to access the specific information without go through the entire system.                                                                               |

| <b>Scenario 2 (looking for the system recommendations)</b> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Scenario</b>                                            | You are a person who is familiar with the museum and its collections. You would like to receive the professional recommendations based on your visit. However, you are unsure about the starting phase of the system.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Screen Descriptions</b>                                 | <p><b>Home Screen</b> - Users click on the view collection list to find the suitable collection.</p> <p><b>Collection List Screen</b> - Users select any of the collection on the list to receive more information related to its background.</p> <p><b>Details Information Screen</b> –Users can see an image of the collection in the background and related information about the current collection. They select any of the options, which are provided from the table such as author, year, materials, and style information.</p> <p><b>Material Screen</b> - Users will get the information of materials which have been adopted to create the collection.</p> <p><b>Detail Information Screen</b> – Users return from the previous page and click on “Bring Me to Next Collection” button to receive the recommendation from the back-end before the screen transfer to the new collection page.</p> |

| Response | Positive                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Result   | At the beginning, the participants were unsure about their goals and desire, so several mistakes occurred by misoperations such as re-entry to the system from the button of starting first collection instead of the link of starting collection list after the recommendations were made. However, such mistakes can always be corrected after the first round of system recommendation. The participants found no obstructions to reach the next collection even if several misoperations have been proceeded. |

Table 8-1 Usability test of paper prototype.

### 8.3.1 Mobile-based user interface

After completing the first usability test, the compositions of UI will be designed and distributed based on this layout structure. According to Oppermann (2002), a user friendly interface is a central issue for the usability of a software product. UI design can be regarded as one of the most important challenges in this research. In order to achieve the ease of use and intuitive manipulation, this system provides four main kinds of designs for interactive museum collections across different facets: a mobile-based interface with various theme pages displaying the detailed information related to the different topics for each collection, a step-by-step interactive quiz dialogs that observe the personal interest, a QR Code based map navigation with 3D virtual interior viewpoints and floor maps displaying location information between collections, and a narrator in the mobile AR environment for enhancing the visitor interaction.

Following the discussion about the disciplines of user interface in IxD from section 7.2.2, the elements of colour influence are concerned primarily with the layout mapping throughout the UI. As we can see in Figure 8-4, the interface is designed and displayed with high contrast presentation due to the on-site museum environment, where indirect lighting has often been used to protect the collections.

With the high contrast screen display, visitors can target the provided information easily during the on-site visiting.

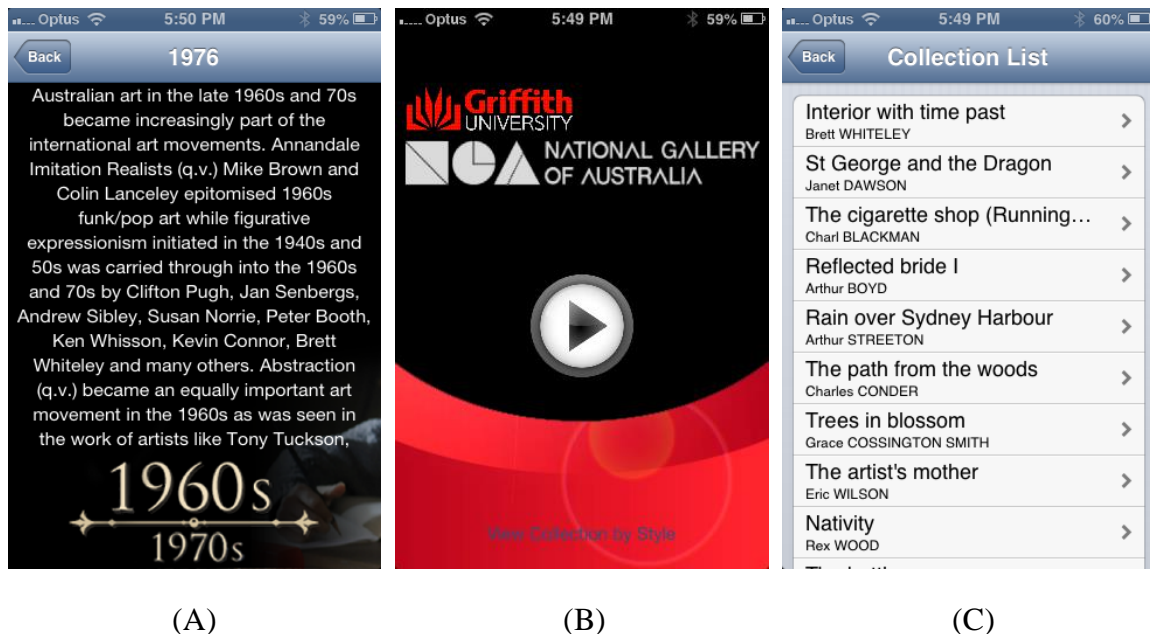


Figure 8-4 Mobile front-end UI layouts.

### 8.3.2 Interactive quiz dialogs

With the intention of discovering visitor's interest, a series of interactive dialogs are used to interact with the visitor during the visit. Figure 8-5 illustrates the process of recommendation when system detected "Year" as the collection preference. As Loïc and his coworker (2008) pointed out that the screen-based devices may interrupt visitors' experience from the exhibits, therefore, only three dialogs are provided in the observation period to minimize unwanted distraction. The quiz will start when visitors trigger the button of "Bring Me To Next Collection" on the main screen of each collection (Fig.8-10 A). An observation dialog will be showed as in Figure 8-5B after interacting with other functions, otherwise 8-5A will be shown instead. If the decision is made by YES button at the observation stage, the recommended collection with location information will be fed back to the visitor as in Figure 8-5C. Otherwise the No button will return the dialog to the detecting mode.

When the GO button is pressed, the visitor can then be guided by the 3D interactive maps which are displayed as Figure 8-6B in association with the location information to the next collection. Finally, the corresponding collection page will be brought up after they reach the new collection. Through the iterative operation of the dialogs, the entire personalized tour trajectory will eventually be established.



Figure 8-5 Interactive quiz dialogs.

## 8.4 Interaction

The factor of interaction in this system is mainly implemented by the frontend UI, as this is the only component that directly faces the users during the visit. Besides the interactive quiz and screen operations that have been introduced in the last section, this system provides deeper three-dimensional ways of presentations to maintain the freshness of users' interest: the interactive 3D maps navigation and an AR based virtual agent. The goal is to extend the time of art appreciation in each collection and ensure the smoothness of visiting experience in on-site venues.

### 8.4.1 Interactive virtual map navigation

Navigation has been recognized as a crucial task when interacting with virtual or physical environments (C.-S. Wang, Chiang, & Ho, 2012). In this system, an HTML5 based interactive virtual museum viewpoint is introduced to work with on-site QR



Codes, which will be placed in each exhibition room across the museum. The QR Code reader equipped on the application as demonstrated in Figure 8-6A will help visitors to target their on-site positions by tagging a QR Code around the museum via smartphone cameras. Through touch screen manipulation, visitors can access the locations of interested collections without missing the track. As Falk (1992) found that the time actually devoted to art appreciation is only around fifteen to forty minutes during a typical art museum visit, successfully reducing the time of searching for collections could improve the museum experience for the first-timer and occasional visitors.

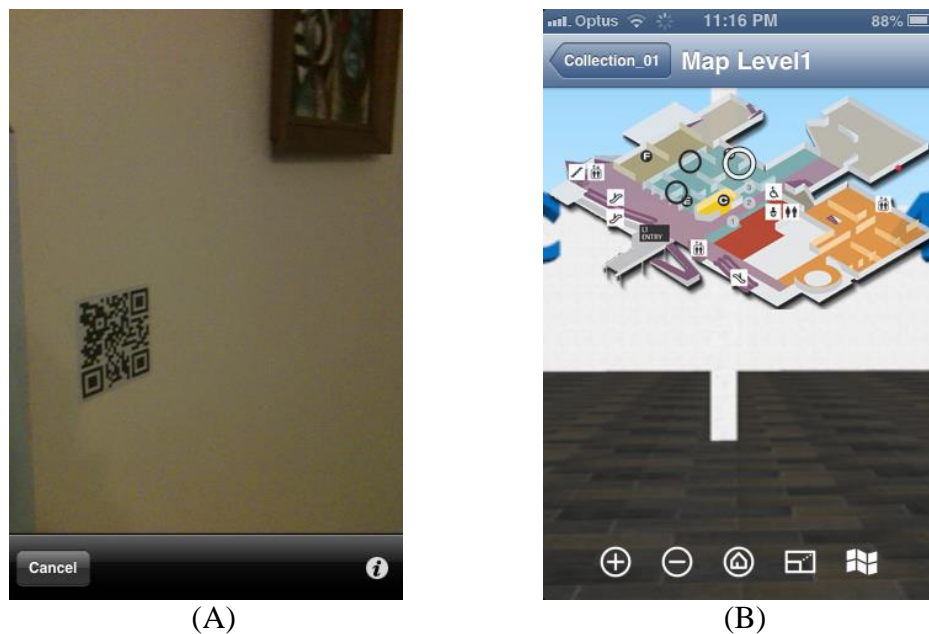


Figure 8-6 Interactive 3D maps navigation with QR Code reader.

### 8.4.2 Mobile AR virtual agent

The use of AR on mobile platform has provided a highly interactive experience (Angelopoulou et al., 2011). As can be seen in Figure 8-7A, an AR based narrator with markerless tracking technique will be adopted as one of the indicators that detect visitor's interest to interact with the on-site environment for visitor engagement. Each on-site collection served as a marker during the visit. When



detection is triggered via camera equipped hand-held devices (this research uses an iPhone 3GS as the interactive platform), a 3D virtual agent with the collection's information will be displayed around the collection dynamically on the screen. In the mean time, the system will attempt to annotate the scenes by tagging the objects on the painting. During the AR session, the agent will act as a personal tour guide and plays a storytelling audio pre-recorded by museum curators, exhibits organiser, or artist themselves in cooperation with dynamic tags to highlight interesting aspects of the painting. In Figure 8-7B, for example, the tags point out "Sydney Harbour" and "Lavender Bay studio" in the painting of "Interior of the time past" created by Brett Whiteley when he sat in his studio at Lavender Bay, with its expansive views across Sydney Harbour. This design not only provides another novel aspect for enhancing museum interaction but also avoids the need to key in a reference number.

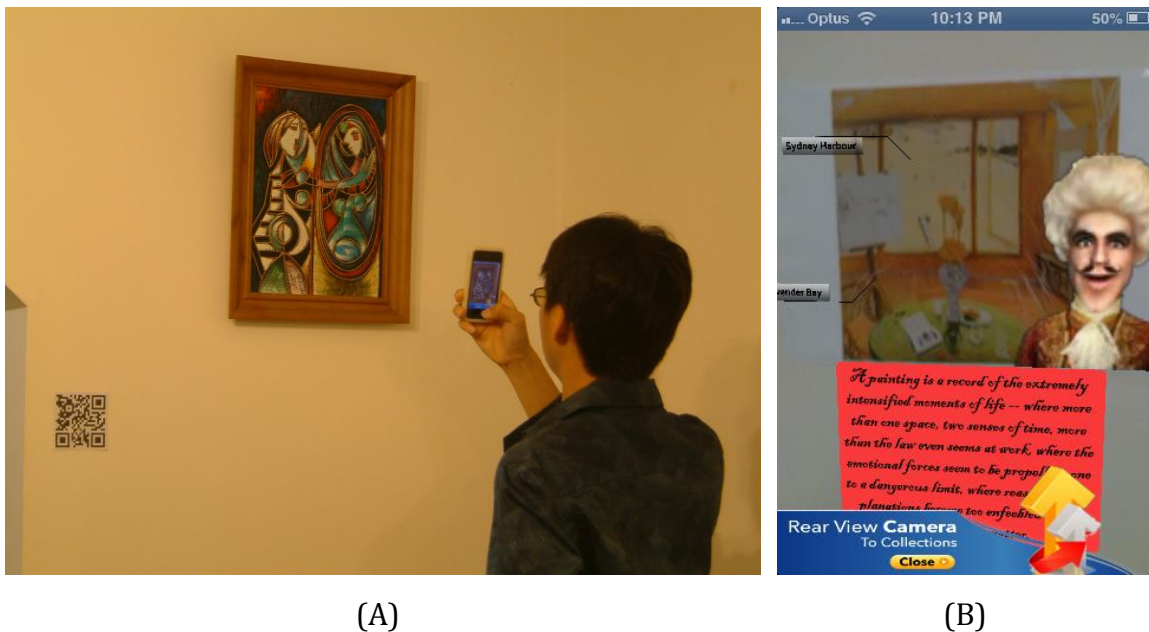


Figure 8-7 On-site markerless Augment Reality presentation

## 8.5 Personalization

The personalization factor of the system in this research is implemented by the composition of an intermediate web platform and a semantic inference engine. In

this effort, visitors can receive a personal visiting history after the visit, which indicates the number of collections that have been inspected during the journey. Most importantly, they can obtain real time recommendations from the system after each appreciation based on their interest factors determined from the previous collections they have visited. In this section, we will describe in detail about how these elements are inter-related for implementing the personalization factor.

### 8.5.1 Semantic recommendation

The development of World Wide Web and the Internet unveils a new epoch for people to search and share information. However, with the huge amounts of information, many research advocates that information needs to be personalized to boost its value (Huynh et al., 2007; Schreiber, 2010). In line with this consideration, Semantic Web has been introduced. In our system, we try to apply semantic inference technology in cooperation with web services to provide personalized information during a museum visit to achieve the goal made by Bowen and Filippini-Fantoni's (2004), that "the museum monologue" can be changed into "a user-centred information dialog" between museums and visitors by enhancing the personalized dimension. Through the semantic database, visitor's preference and interest can be inferred tacitly by observing their behaviour on-site during their interactions with the front-end system. By using the web service, a visitor's personal visit history can also be preserved during the data communication for further analysis or on-site experience improvement. Below, we outline the framework of this database, and discuss how the semantic metadata can be implemented to establish a personalized tour trajectory.

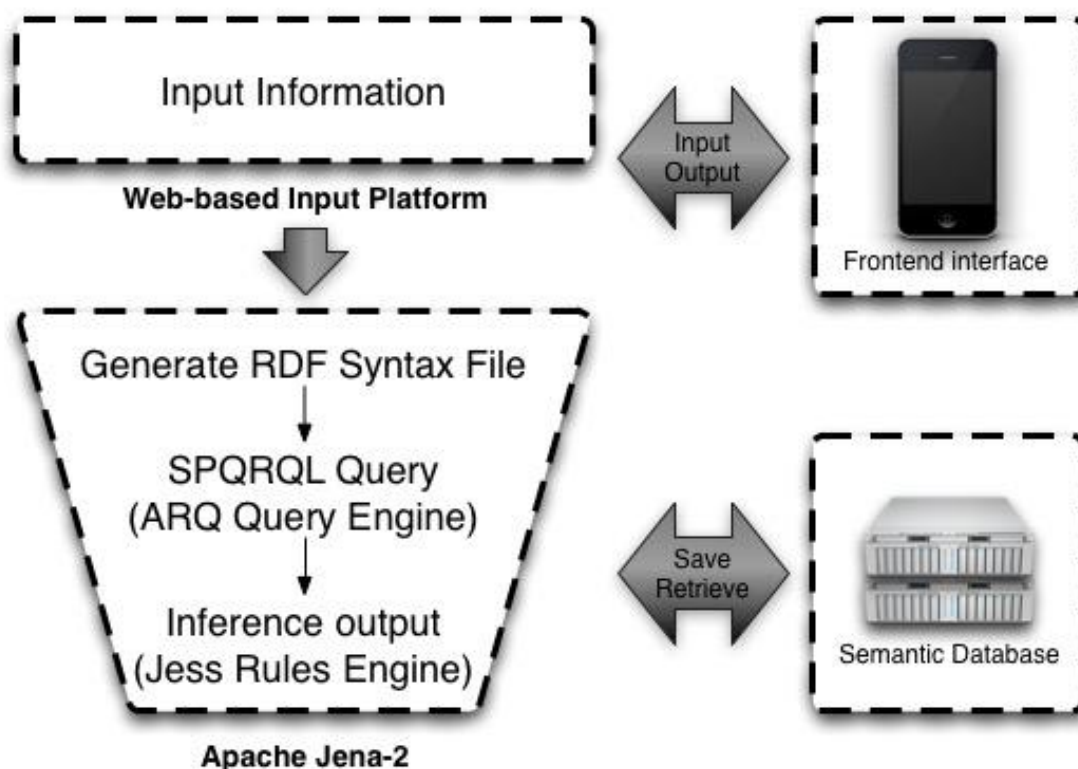


Figure 8-8 Framework of the back-end semantic database.

Figure 8-8 depicts an overview framework of the intermediate web service and back-end semantic database. In this framework, an HTML platform is adopted as an intermediate input/output platform to integrate several tools such as PHP, MYSQL, and JSON<sup>13</sup> for storing the collections information, visitor's personal visit history, and passing/receiving the data. The ontology of Cidoc-CRM and the java framework of Apache Jena-2 are used in the semantic database for the handling, processing, inference, and output of result. Therefore, the digital information of this system is presented by the Web Ontology Language (OWL)-encoded Cidoc-CRM instances. When input keyword is sent to the database via intermediate platform, these instances and various inference rules will be transferred to the Apache Jena-2 rule

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<sup>13</sup> JSON (JavaScript Object Notation) is an independent text-format language that provides a data-interchange format between C-family of languages. If a system is written by more than one programming languages, JSON may provide a bridge for communicating the data within the system.

base system after the SPARQL Protocol and RDF Query Language (SPARQL) queries, and the inference output which generated by Jess rule engine will be passed back to the visitor through the same channel. A discussion of the components we have adopted to develop the entire back-end system will be given next.

*Apache Jena-2* - Apache Jena-2 is an open source Java framework, in which the RDF/XML syntax and other types of RDF representation such as, N3 and N-TRIPLES can be created, modified, queried, and inferred by using different Application Programming Interface (APIs) (Min, Jianping, Yang, & Henxing, 2005). In the Semantic Web, RDF/XML syntax is processed as a set of triples statement, which contains the S-Subject, P-Predicate, and O-Object. Predicate is a property of role that links the Subject and Object. For instance, in order to represent the phrase of "The author's name is Brett Whiteley" in RDF, the triple statement will represent "The author's name" as a subject, "is" as a predicate, and "Brett Whiteley" as an object. When RDF/XML syntax is created, a series of syntax queries will be made by SPARQL statement via the ARQ query engine. The purpose is to display the information such as location, title, and size of collection for further reasoning by the Jess rules engine.

*Cidoc-CRM* - Assessing and managing the large collections data is a crucial task for the content management system due to the need to handle semantic querying, where the visitor's interest and contextual information are important parameters to consider. In this research, we adopted Cidoc-CRM as introduced in section 4.3.1 to manage the collections information for database query and inference. Cidoc-CRM is an OWL based ontology, which was developed with ISO 21127 standard since its first release in 2006 to specifically deal with semantic information for historical artefacts such as those found in museums and archives (Doerr, Ore, & Stead, 2007). The latest update of this ontology that we are currently using is based on the version 5.0.4, which was released by Nick Crofts, Martin Doerr, Tony Gill, Stephen Stead, and Matthew Stiff in December 2011. As we can see from Table 8-2, several properties have been selected to describe the topics of each collection using this ontology.

| Descriptions     | Properties                  | Collection Information                  |
|------------------|-----------------------------|-----------------------------------------|
| Author's Name    | P52_has_current_owner       | Brett WHITELEY                          |
| Residency        | E53_Place                   | Australia                               |
| Language         | E56_Language                | English                                 |
| Influence        | P15_was_influenced_by       | Francis Bacon                           |
| Participation    | P158_occupied               | "Recent Australian Painting" exhibition |
| Site             | E27_Site                    | The Tate Gallery                        |
| Period I         | E4_Period                   | Cold War                                |
| Period II        | p10_falls_within            | Postmodernism and Deconstructivism      |
| Year             | P4_has_time-span            | 1976                                    |
| Type I           | P2_has_type                 | Painting                                |
| Type II          | E55_Type                    | still life                              |
| Technique        | P32_used_technique          | Oil-painting                            |
| Classification   | P41i_was_classified_by      | Social Comment & Hard Edged Abstraction |
| Technique I      | P33_used_specific_technique | Canvas                                  |
| Technique II     | P33_used_specific_technique | Oil                                     |
| Location         | P7_took_place_at            | 5D                                      |
| Measurement/Size | P91_has_unit                | 182.0 h x 200.0 w cm                    |
| Title            | P102_has_title              | Interior with time past                 |

Table 8-2 Mapping between information for the one of Brett WHITELEY's work.

## 8.5.2 Web-based input platform

The input HTML platform as shown in Figure 8-9A is a web-based interface that allows curators to manage information related to the specific collection in the database and stores the personal visit history. In this platform, the input data will be transferred into RDF/ Extensible Markup Language (XML) syntax automatically. In this work, we aimed to build a user-friendly interface for curators and managers to connect the Cidoc-CRM standard properties with different topics by typing the data on a webpage. For instance, "The Author's Name" and "The Year" on the webpage will refer to the properties of "P52\_has\_current\_owner" and "P4\_has\_time-span". Figure 8-9B demonstrates the output of RDF/XML syntax based on the input data. The purpose of this platform is to allow curators and museum staffs to manage metadata easily by inputting the semantic metadata and then storing it into the MySQL database.

http://localhost/test/form.html Describe Author and Image...

## The Forms

Some information about author and photo.

The Author's Name  
(P52\_has\_current\_owner) Brett WHITELEY

The Year  
(P4\_has\_time-span) 1976

Type  
(P2\_has\_type) Painting

Classification  
(P41i\_was\_classified\_by) Social Comment & Hard Edged Abstraction

Technique I  
(P33\_used\_specific\_technique) Canvas

Technique II  
(P33\_used\_specific\_technique) Oil

Location  
(P7\_took\_place\_at) 5D

Measurement/Size  
(P91\_has\_unit) 182.0 h x 200.0 w cm

Title  
(P102\_has\_title) Interior with time past

GENERATE RDF FILE RESET DATA

(A)

http://localhost/test/generate\_rdf.pl Generate RDF File

```
<rdf:RDF
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:owl="http://www.w3.org/2002/07/owl#"
  xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
  xmlns:crm="http://www.cidoc-crm.org/rdfs/cidoc_crm_v5.0.4_official_release.rdfs#"
  xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#" >
  <rdf:description rdf:about="http://localhost/#image10_html">
    <crm:p102_has_title> Interior with time past</crm:p102_has_title>
    <crm:p91_has_unit> 182.0 h x 200.0 w cm</crm:p91_has_unit>
    <crm:p7_took_place_at> 5D</crm:p7_took_place_at>
    <crm:p33_used_specific_technique> Oil</crm:p33_used_specific_technique>
    <crm:p33_used_specific_technique> Canvas</crm:p33_used_specific_technique>
    <crm:p41i_was_classified_by> Social Comment & Hard Edged Abstraction</crm:p41i_was_classified_by>
    <crm:p2_has_type> Painting</crm:p2_has_type>
    <crm:p4_has_time-span> 1976</crm:p4_has_time-span>
    <crm:p52_has_current_owner>Brett WHITELEY</crm:p52_has_current_owner>
  </rdf:description>
</rdf:RDF>
```

(B)

Figure 8-9 HTML input platform and RDF/XML syntax output.

## 8.6 Education

The facet of education is one of the most common concerns of museum

digitalization. Except storytelling AR presentation, information pool is another instance of education factor presented in this system. The pool is located in the bottom of each collection page as displayed in Figure 8-10A, which provides related information about the collection. In this system, every collection is divided into five different topics: the name of the author, the year of creation, the type of materials used, the style and size of collection. On one hand, such information provides visitors with the professional knowledge needed to allow a deeper understanding of the collection during the visit. On the other hand, the pool can also act as the detection platform for observing the visitors' potential interest without extra operations during their knowledge acquisition.

As can be seen from the screenshots of Figures 8-10B, C, each topic is presented by a theme page, which presents the features about the topic. According to Carretti (2007), imagery is one of the strategies to make items more salient. A storytelling theme page can assist visitors to understand the collections quickly and significantly enrich their visiting experience. For instance, the art movement of Modernism in Australia could be related to the theme which displays the period between the First and Second World War. For the content, while the information should be provided as detail as possible in line with the needs of visitor, however, as argued by Templeton (2011), any interpretive content could potentially distract from the art appreciation especially when it is provided through mobile devices in which the display of content is limited by the size of the screen. Nevertheless, she also pointed out that, a well-structured content with appropriate length may support visitors while avoiding the distraction. Therefore, each theme page is designed to contain no more than 100 words. The purpose is to seek a balance between visitors' senses and system functionality.



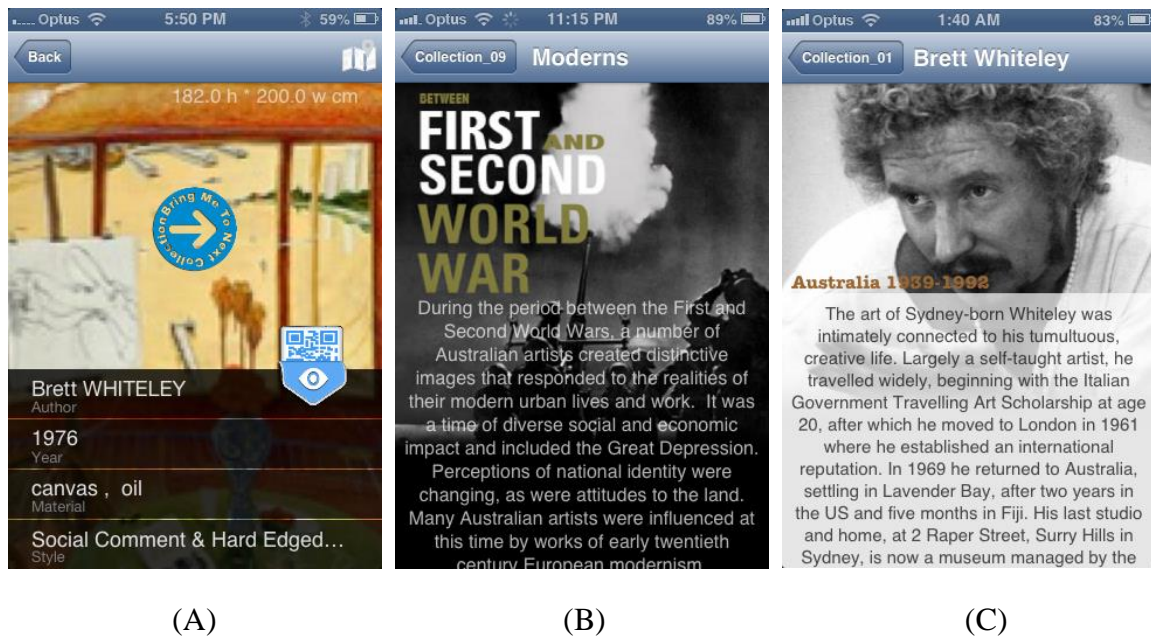


Figure 8-10 Mobile front-end UI layout.

## 8.7 Repackaging

Repackaging can be regarded as the most valuable facet for curators and system developers, and the key element for the distribution of digital collections. A repackable system may help museum curators to flexibly manage the digital component in accordance with each exhibit and further increase the exchange of idea between organizations. Besides the adoption of SOA framework that we have discussed in section 6.2, this system provides a collection management platform for curators and system developers to management the information and components that are displayed on the mobile interface.



| CollectionName          | AuthorName | LastName | Year | Materials | Materials1 | Style                                   | Location | CollectionImage                          |
|-------------------------|------------|----------|------|-----------|------------|-----------------------------------------|----------|------------------------------------------|
| Interior with time past | Brett      | WHITELEY | 1976 | canvas    | oil        | Social Comment & Hard Edged Abstraction | 5D       | 4D0BFF17-5810-4644-A550-D35EE090D4A8.png |

Figure 8-11 Collection management system.

The input collection management system is deployed and connected with intermediate platform in which the curatorial teams would be able to create collection datasets with related information using the form that is shown in Figure 8-11. It is designed to contain all the necessary information about the collections that is listed in table 8-2 for semantic retrieval. It is developed using common Web languages, i.e. PHP and CSS. When a team member inserts the detail information into the given text field and clicks the submit button, a record will be added to the intermediate database, and the result could be displayed instantly in the given table as well as reloading to the mobile user front-end when visitors retriggering the application. By clicking on the “Detail Information” button on the front page, the operators can also add and modify the additional information specifically by selecting the name of collection from the dropdown menu as displayed in Figure 8-12. In this way, the system not only provides a multi-user platform for authorized members to cooperate with each other, but also breaks up the limitations of time and space, as the data can be added, modified and retrieved anytime without interrupting users’ on-site visiting experience.

Dashboard

Collection Name\* Interior with time past

Author Information\*

Year Information\*

Material Information\*

Author Image\*

Year Image\*

Material Image\*

| AuthorInfo | YearInfo | MaterialInfo                                                                                  | AuthorImage | YearImage | MaterialImage |
|------------|----------|-----------------------------------------------------------------------------------------------|-------------|-----------|---------------|
|            |          | The artwork which created by canvas and oil is typically called Oil painting. The linseed oil |             |           |               |

Figure 8-12 The collection detail page.

Moreover, due to the adoption of common languages, the system can easily be deployed into different organizations for combining indexes and sharing information if the exhibits of collections are distributed into various venues across different museums. The feature of SOA protocol also endows the separate use of each component, which can be controlled and switched from the system to ensure the quality of user experiences between occasions. For example, the AR button would only appear on the front-end collection page if the users visit a virtual resource equipped collection.

## 8.8 Discussion

This chapter expounded the development of PETTA with causes and effects by leading the concepts and theories that have been systematically discussed in the previous chapters into the prototype implementation. The system can be regarded

as a verification tool that helps us to prove the proposed theory and framework that we have made in chapters 4 and 7. It asserted that the on-site visiting experience enhancement should be embodied into the facets of Visualization (Casual InfoVis), Personalization, Interaction, Education, and Repackaging. The first contribution is that the on-site visiting experience will be enhanced notably when this framework is adopted by the museum organizations. For the second contribution, we stated that if the dimension of Behaviour is properly defined in IxD during system development, the effects of two-way feedback can be reflected by Time, thus to achieving the purpose of personalization. In the next chapter, we will present the second round of usability test before proceeding to the real user evaluation.

# 9. Testing and Evaluation

## 9.1 Introduction

Following the first round of card-sorting test presented in section 8.3 that confirmed the operational logic of the thought process on the mobile interface, this chapter will focus deeply on the second round of usability test and real users' evaluation. The test is done by the Cognitive Walkthrough (CW) method with a list of tasks developed based on the cognitive dimensions, in which the usability issues of the entire system will be addressed. In the next section, we will introduce this usability inspection method and each detailed procedure of the test by unpacking the tasks that are designed for this system. In this test, any potential usability problems will be clarified before conducting the real user participation survey. The judgment of whether the prototype has met the research expectation will be discussed at the end of this chapter based on the test outcomes and evaluation results.

## 9.2 Cognitive Walkthrough

CW is a usability inspection method that is widely used in HCI for understanding the effectiveness of interaction system. According to Wharton and his colleagues (1994), CW (also called Cognitive Jogthrough) is a task-specific evaluative research method used in the design and deployment periods of interactive systems

by individual or groups. As Lewis and Rieman (1993) pointed out, without the need to actually performing testing using real users, this methodology could benefit developers by identifying the problems in user-centred design and user personas. It was first exploited in the 1990s, focusing on the ease of use for new users to accomplish tasks with the system. The methodology is deployed through five distinct procedures, which starts off by defining the input to the walkthrough, then convenes the analysis by cataloguing different users such as visitors and managers before designing the actions of walking through. When the actions have been set up, walking through the action sequences for each task will be followed by recording critical information. Finally, any problem in the system framework and interface design will be exposed by evaluating the recorded information.

### 9.2.1 Defining the input to the walkthrough

Clearly circumscribe the input resources is a crucial step of CW method. Wharton has defined four questions to establish a cognitive scenario at each step, which includes (Wharton et al., 1994):

1. Who will be the users of the system?
2. What task(s) will be analysed?
3. What is the correct sequence for each task and how is it described?
4. How is the interface defined?

The fourth question is initially designed for the paper description of the interface, which has been done before the actual development. In this stage, we will not address this question because the interfaces are already available from our implementation. For the first question, Figure 9-1 displays the potential users that are targeted by the system within the museum. Three groups, namely general visitors, museums and exhibits curators, and system administrators are nominated as “users” to sustain the entire framework. However, in consideration of the different

knowledge background and technical experiences in each group, we have narrowed down the subjects of evaluation in this test into:

- (1) Visitors who visit museum casually with no technical experiences and art background.
- (2) Museum and exhibits curators who are equipped with strong aesthetic wisdom and have the ability to manage the collection's information.
- (3) System administrators who have general technical background and are familiar with common programming languages such as JAVA, PHP, and JSP.

These subjects are assumed to meet the requirements of each group to simulate the various possible situations.

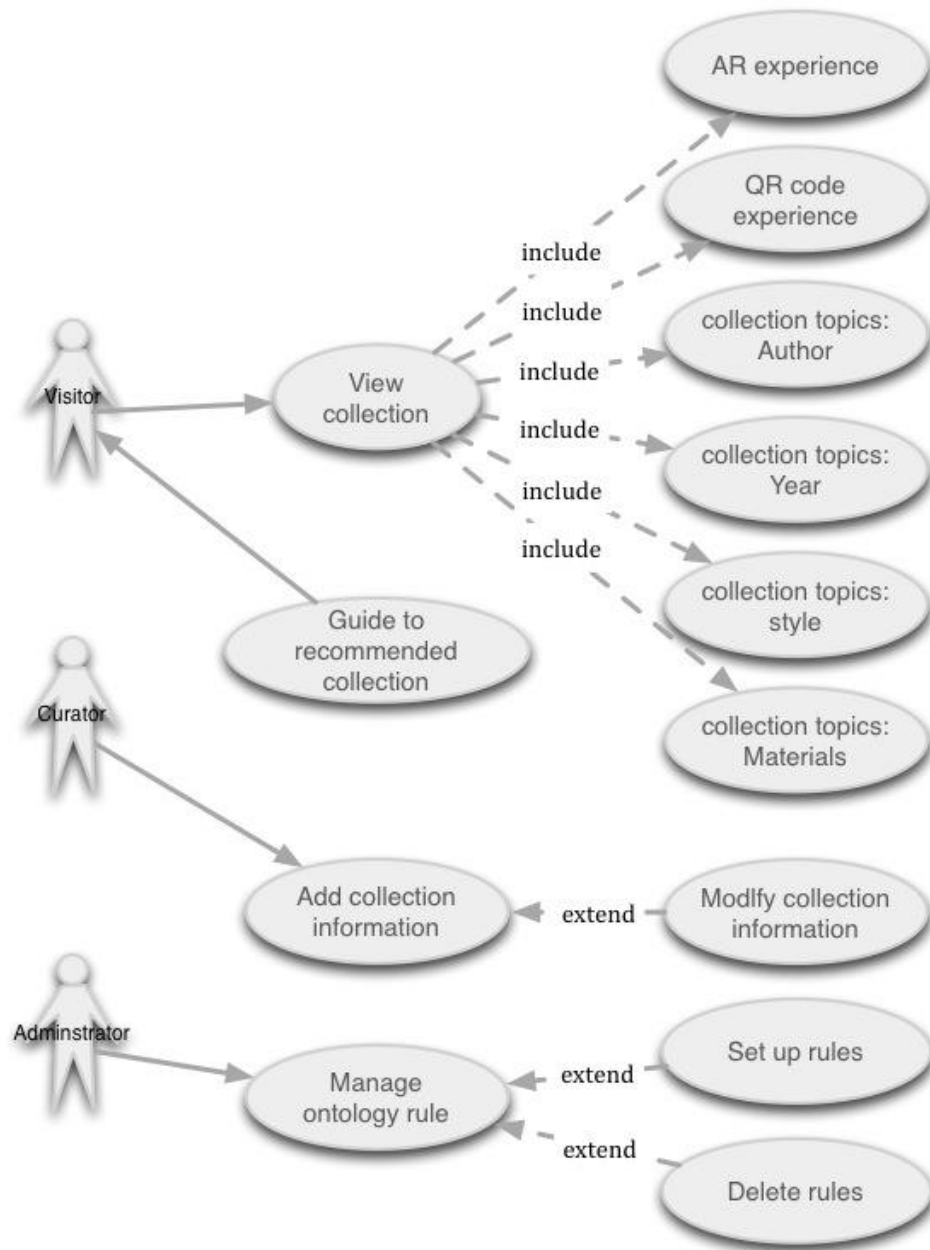


Figure 9-1 Use case diagram.

## 9.2.2 Defining the tasks

The second question is to define the tasks that will be analysed under the cognitive scenario. In order to develop the tasks representatively, we have broken down the inducement of tasks into a number of questions based on the cognitive

dimensions framework, which was defined by Green and Petre (1996) to evaluate the techniques of interactive devices and designs of programming languages in HCI. The framework was first proposed in 1996 with the composition of 14 dimensions, *Abstraction gradient, Closeness of mapping, Consistency, Diffuseness / terseness, Error-proneness, Hard mental operations, Hidden dependencies, Juxtaposability, Premature commitment, Progressive evaluation, Role-expressiveness, Secondary notation and escape from formalism, Viscosity, and Visibility*. In this research, we attempted a CW by using these dimensions as the foundation of the tasks for evaluating the effectiveness of users experience in various aspects. The questions of interest are listed for different groups as below:

*For Visitor:*

1. Will the interface be accessed effectively without training?
2. Will the visitor receive extra information accurately and conveniently during the visit?
3. Will the information be provided cognitively?
4. If mistakes are made by operations or decisions, will the visitor be able to go backward?
5. After the appreciation of current collection, will the new collections be provided accordingly and proactively?
6. When progressing with the observation, will the visitors understand the feedback they get, so they can go to the next step with confidence?
7. Will the visitor be able to be guided by the system to the next collection?
8. Will the personal recommendations be made persistently until the end of visit?



9. Once the visitors finish the visit, will they receive any feedback regarding the visit?

*For Curator:*

1. Will the collection's information be readily accessible?
2. Will the curator be able to manage the collection's information according to the exhibits?
3. Once visitors finished the visit, will visitors' behaviours be provided for further inspections?
4. Will the recorded data be valid and analysable even if the visitor did not finish visiting the entire collections?

*For Administrator:*

1. Can the system be maintained without requiring high-level of technical expertise?
2. Can the system be created economically using existing technologies?
3. Has the issue of technological obsolescence in system development been addressed properly?
4. Can the system be serviced and maintained in an operative condition expeditiously?
5. After the system is created, will the modules be expandable for further development?

Based on above questions, each group was given a specific task to simulate the cogitative scenario. The task for Visitor was to complete a cycle of visit by using the

system for exploring a set of collections, whilst Curator's task was to apply the system to a new exhibit and receive visiting data from each visitor. The task of Administrator was to update inference rules from the database after the new collections or exhibits were set up by curator.

### 9.2.3 Evaluators/Participants

In the CW method, both evaluators and participants have to be set up as fictive users to represent an expert reviewer and the targeted user communities. In this work, two new users were selected. One played the role of an evaluator to inspect the defined tasks during the walkthrough, and the other acted as the participant to represent the targeted user communities to go through the defined tasks based on the cognitive dimension questions via designed action sequences, which will be discussed next.

### 9.2.4 Walk through action sequences for each task

After defining the input subjects and tasks, the actions and sequences of tasks will need to be defined. The action sequences of Visitor as Task1 are:

- a) Select an on-site collection and launch the interface, then click the play button or collection list to enter a collection page.
- b) Freely click the sub-theme pages to navigate through the collection information.
- c) Click the AR button and face the camera to the collection for listening or exploring the collection via virtual agent and animation.
- d) Return to the collection page and click "Bring Me To Next Collection" for

- activating the interactive quiz dialogs.
- e) Click “Yes” on the observation dialogs.
  - f) Click “Yes” on the recommendation dialogs.
  - g) Click QR Code button for searching the current location in association with interactive map navigation to the recommended collection.

The action sequences of Curator as Task2 are:

- a) Launch the input HTML platform and enter or update the new collection information by filling out the blank form.
- b) Click “GENERATE RDF FILE” on the input HTML platform.
- c) Log into the system and download the previous visiting histories from the database.
- d) Analyse the data of past visitor’s trajectories for optimising future exhibit.

The actions sequences of Administrator as Task3 are:

- a) Launch the Apache Jena via Eclipse.
- b) Choose the existing rules of inference.
- c) Add or update the rules based on the collections curator has created.

The selected groups go through the whole system for completing the tasks, and the critical information obtained are highlighted in the next section.

## 9.2.5 Recording critical information

Recording the critical information by walking through the defined tasks can expose the weaknesses of the interactive system and efficiency of the user interface. Lewis and Rieman (1993) recommended four questions for critiquing the tasks:

- A. Will the users be trying to produce whatever effect the action has? – It ensures the users can pursue the logical thinking.
- B. Will the users be able to notice that the correct action is available? – It evaluates the levels of user-friendliness in the designed interface.
- C. Once users find the correct action at the interface, will they know that it is the right one for the effect they are trying to produce? – It ensures the intuitive grasp of each function.
- D. After the action is taken, will users understand the feedback they get? – It ensures system can perform a proper feedback after the actions is completed.

Keeping these questions in mind, the evaluator will be able to distinguish the success or failure of the tasks, in which the participants went through based on the answers to the questions A to D defined by cognitive dimensions. We evaluated both actions and walkthrough questions in order to obtain critical information from the tasks.

Table 9-1 is the result of execution applying questions A-D to each action. The symbol “Y” (Yes) indicates a well-defined action that can be walked through without extra assistance while an “N” (No) identifies a possible usability problem that may interrupt the potential experience during the interaction. The result R shows either “P” (Pass) or “F” (Failure). In this table, Task1 (c), (g), usability problems were identified on questions A and B, where visitors may skip AR interaction before

proceeding to the next action if this function is available, or have difficulty to locate QR function on the collection screen. Task2 (b) was identified on questions C and D that indicate curators may confuse the name of the generated buttons on the input HTML platform.

| T<br>1 | (a) | (b) | (c) | (d) | (e) | (f) | (g) | T<br>2 | (a) | (b) | (c) | (d) | T<br>3 | (a) | (b) | (c) |
|--------|-----|-----|-----|-----|-----|-----|-----|--------|-----|-----|-----|-----|--------|-----|-----|-----|
| A      | Y   | Y   | N   | Y   | Y   | Y   | N   | A      | Y   | Y   | Y   | Y   | A      | Y   | Y   | Y   |
| B      | Y   | Y   | N   | Y   | Y   | Y   | N   | B      | Y   | Y   | Y   | Y   | B      | Y   | Y   | Y   |
| C      | Y   | Y   | Y   | Y   | Y   | Y   | Y   | C      | Y   | N   | Y   | Y   | C      | Y   | Y   | Y   |
| D      | Y   | Y   | Y   | Y   | Y   | Y   | Y   | D      | Y   | N   | Y   | Y   | D      | Y   | Y   | Y   |
| R      | P   | P   | F   | P   | P   | P   | F   | R      | P   | F   | P   | P   | R      | P   | P   | P   |

Table 9-1 Execution of tasks.

After the evaluation of each action, the information about the defined questions in the focused groups will be recorded in the next step. Table 9-2 lists the results (Y/N), the affected actions (the bolds are the failed actions), and reasons for the walkthrough questions based on the execution. It appears that the failure reasons of Task1 are well match to the results from the first round of test.

| Questions          | Actions |     | Reasons                                                                                                                                                                                                                                                                                                                                                                                                                       |
|--------------------|---------|-----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Task1: For Visitor |         |     |                                                                                                                                                                                                                                                                                                                                                                                                                               |
| (1)                | Y       | (a) | The entire system is developed along the UCD principle. On the start page of the front-end interface, only two buttons are provided for visitors to start either by selecting the collection of interest from the collection list or starting from the first collection near the entrance. This design offers the closest way to simulate the behaviors of both new visitors and experienced visitors when they visit museum. |
|                    |         | (b) |                                                                                                                                                                                                                                                                                                                                                                                                                               |
|                    |         | -   |                                                                                                                                                                                                                                                                                                                                                                                                                               |
| (2)                | N       | (b) | The front-end interface supports vast collection knowledge by cataloging the information systematically into different theme pages. However, the use of AR is identified as a usability problem although it provides an innovative approach for visitors to enhance their art appreciation and understand without needing to read the content.                                                                                |
|                    |         | (c) |                                                                                                                                                                                                                                                                                                                                                                                                                               |
|                    |         | -   |                                                                                                                                                                                                                                                                                                                                                                                                                               |
| (3)                | Y       | (b) | The collection’s information is represented by different theme pages according to the features used. As stated by Carretti (2007), the                                                                                                                                                                                                                                                                                        |

|                    |   |     |                                                                                                                                                                                                                                                                                          |
|--------------------|---|-----|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                    |   | -   | knowledge will therefore be provided cognitively, and visitors can be led easily without memorizing each collection.                                                                                                                                                                     |
|                    |   | -   |                                                                                                                                                                                                                                                                                          |
| (4)                | Y | (e) | During the interaction, the interactive quiz dialogs provide a deny function for returning the dialog to the detecting mode when visitors felt that the suggestion is not suitable for them.                                                                                             |
|                    |   | (f) |                                                                                                                                                                                                                                                                                          |
|                    |   | -   |                                                                                                                                                                                                                                                                                          |
| (5)                | Y | (d) | After the current collection appreciation, the new collection will be recommended proactively by the semantic database based on the result of observation dialogs and visitor’s behaviour.                                                                                               |
|                    |   | (e) |                                                                                                                                                                                                                                                                                          |
|                    |   | (f) |                                                                                                                                                                                                                                                                                          |
| (6)                | Y | (e) | The observation is proceeded by a series of interactive quiz dialogs, just like talking to an expert who understand your visiting behaviours and the museum collections.                                                                                                                 |
|                    |   | (f) |                                                                                                                                                                                                                                                                                          |
|                    |   | -   |                                                                                                                                                                                                                                                                                          |
| (7)                | N | (g) | So far, visitors can only be guided by interacting with the 3D virtual map, and locating a rough position by using position markers based on QR Codes. The interior localization function has not yet been supported due to the immature/expensive technology.                           |
|                    |   | -   |                                                                                                                                                                                                                                                                                          |
|                    |   | -   |                                                                                                                                                                                                                                                                                          |
| (8)                | Y | (d) | The system is designed by using an endless cycle framework in which the recommendation will be provided after every single appreciation, so that visitors can begin from any collection and stop in any place within the on-site museum without breaking the entire visiting experience. |
|                    |   | -   |                                                                                                                                                                                                                                                                                          |
|                    |   | -   |                                                                                                                                                                                                                                                                                          |
| (9)                | N | -   | The system only provides visiting history as the feedbacks. These feedbacks are unavailable to the visitors. It is only available for curators and administrators to analyse the visitor’s behaviours.                                                                                   |
|                    |   | -   |                                                                                                                                                                                                                                                                                          |
|                    |   | -   |                                                                                                                                                                                                                                                                                          |
| Task2: For Curator |   |     |                                                                                                                                                                                                                                                                                          |
| (1)                | Y | (a) | The collection informations are stored and managed by MYSQL, so that it can be accessed by MS Excel or the input HTML platform without technical support once the database is created and set up properly.                                                                               |
|                    |   | -   |                                                                                                                                                                                                                                                                                          |

|                          |   |     |                                                                                                                                                                                                                                                                                                                                                                                                           |
|--------------------------|---|-----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                          |   | -   |                                                                                                                                                                                                                                                                                                                                                                                                           |
| (2)                      | Y | (a) | The back-end system provides an input HTML platform for curators to manage the data in each collection, so that information about the exhibits can be added, updated or removed readily.                                                                                                                                                                                                                  |
|                          |   | -   |                                                                                                                                                                                                                                                                                                                                                                                                           |
|                          |   | -   |                                                                                                                                                                                                                                                                                                                                                                                                           |
| (3)                      | Y | (c) | During the visit, all visiting history will be stored in the intermediate web service, which offers a stage for communicating between front-end and back-end. When visitors finish their appreciation, these data can be retrieved for further analysis such as the optimization of on-site tours or in designing an attractive exhibition by identifying the most visited collections.                   |
|                          |   | (d) |                                                                                                                                                                                                                                                                                                                                                                                                           |
|                          |   | -   |                                                                                                                                                                                                                                                                                                                                                                                                           |
| (4)                      | Y | (c) | Due to the adoption of an endless cycle framework, visitors do not need to visit all collections or exhibits within the museum for curators to access the data of visitors' behaviors.                                                                                                                                                                                                                    |
|                          |   | (d) |                                                                                                                                                                                                                                                                                                                                                                                                           |
|                          |   | -   |                                                                                                                                                                                                                                                                                                                                                                                                           |
| Task3: For Administrator |   |     |                                                                                                                                                                                                                                                                                                                                                                                                           |
| (1)                      | Y | (a) | The entire system is established based on existing technologies with common programme languages such as Objective-c, JAVA, PHP, and JSP, so that a high-level of technical skills is not necessary for creating and maintaining the system.                                                                                                                                                               |
|                          |   | (b) |                                                                                                                                                                                                                                                                                                                                                                                                           |
|                          |   | -   |                                                                                                                                                                                                                                                                                                                                                                                                           |
| (2)                      | Y | (a) | The system framework is constructed under the free and open source software (OOS) such as Jena, PHP/MYSQL database, Xcode. The only charge in this case is the iOS ad hoc provisioning profile for the deployment of the front-end interface in the designated devices. However, the cost can be waived by migrating the front-end from iOS to Android environment which is a free distribution platform. |
|                          |   | (b) |                                                                                                                                                                                                                                                                                                                                                                                                           |
|                          |   | -   |                                                                                                                                                                                                                                                                                                                                                                                                           |
| (3)                      | Y | (a) | The whole system consists of different components. The front-end interface does not maintain its' own bespoke system, and the back-end database can be run on commodity hardware with no special requirements. In this way, the risk of technological obsolescence will be reduced to the minimum.                                                                                                        |
|                          |   | (b) |                                                                                                                                                                                                                                                                                                                                                                                                           |
|                          |   | (c) |                                                                                                                                                                                                                                                                                                                                                                                                           |
| (4)                      | Y | (b) | The system is deployed based on the object-oriented framework in which the components can be operated, served, and maintained separately without influencing each other. In this way, the system errors will be identified quickly and be solved expeditiously.                                                                                                                                           |
|                          |   | (c) |                                                                                                                                                                                                                                                                                                                                                                                                           |
|                          |   | -   |                                                                                                                                                                                                                                                                                                                                                                                                           |

|     |   |     |                                                                                                                 |
|-----|---|-----|-----------------------------------------------------------------------------------------------------------------|
| (5) | Y | (c) | The concept of object-oriented design makes the system extendable without changing the entire system framework. |
|     |   | -   |                                                                                                                 |
|     |   | -   |                                                                                                                 |

Table 9-2 Critical information of each task.

## 9.3 Real user participation Evaluation

| Demographic Item |          |
|------------------|----------|
| Age (median)     | 28 years |
| male / female    | 16/5     |

Table 9-3 Summary of participants' demographic information.

After completing two rounds of usability tests, the prototype will then be evaluated by a series of real user participation test. The goal is to evaluate our framework in a real physical scenario. The evaluation was conducted in accordance with the ethical clearance as attached in Appendix 6. There were more than 100 invitation emails (Appendix 2) sent out to different academics groups around the campus with 26 positive feedbacks in the initial contact stage. Several criteria and scenarios were set up to narrow down the recruitment, which includes the participants will be adults (> 18 years old) of both sexes who visit museum on a casual basis with no assumed technical experience and art background, and is available to be recruited randomly from the replied mail list at the Griffith Nathan campus. In consideration of above criteria and users' availability, 21 participants were recruited into this survey. Table 9-3 indicates the distribution of participants' demographic information. They were requested to interact with the front-end system by following a series of information and recommendations that the system provided. A short introduction and instructions about the survey were provided at the beginning of the operation, but no other information was given during the evaluation session. The participants also had the opportunity to ask questions



related to the system manipulation if required. After the engagement, the volunteers were asked to fill a hard copy survey sheet (Appendix 5) related to the user experience aspect of the prototype.

### 9.3.1 Data collection

Due to lack of access to a museum or suitable exhibits, the survey was conducted in a simulated physical museum environment in which several collections and related components such as QR Codes and AR were set up for the experiment. The information sheet and consent form as enclosed in Appendix 3 and Appendix 4 were provided and required to be signed before the survey. The survey sheets were only given to the participants after the system interaction session in order to reduce bias or distraction to the visiting experience. The users' data was collected by a carefully constructed questionnaire, which was designed based on the 11 questions with responses ranging from scale 1 (strongly disagree) to 5 (strongly agree), as presented in Appendix 5. The participants need to answer all questions in the user survey sheet after interacting with the system. The entire process took about 10-15 minutes to complete.

### 9.3.2 Participant feedbacks

One of our primary concerns of this survey is to evaluate the effectiveness of the proposed framework and theory in the real scenario, which specifically targets on the visiting reactions, feeling, and overall user experiences as mentioned from the research statement at the beginning of this thesis. Table 9-4 lists the scores of each question in different participants. The X-axis indicates the number of questions while the Y-axis represents the number of participants. As can be noted, most of the participants expressed satisfaction about this new way of museum visiting and agreed that it would enhance the user experience. With the average scale of 4 in the overall result, two questions (questions 5 and 7) related to the interface layout

design particularly received the highest scale as shown in Table 9-5. These results reflect the obvious advantages arising from the adoption of Casual InfoVis in the system development, as the first-person style of guidance would reduce technophobia<sup>14</sup> and help visitors to concentrate more on the knowledge receiving and collection exploration tasks when information and recommendations are provided automatically by technologies.

| Participant \ Question | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | Q11 |
|------------------------|----|----|----|----|----|----|----|----|----|-----|-----|
| 1                      | 4  | 4  | 5  | 4  | 4  | 4  | 3  | 5  | 5  | 4   | 4   |
| 2                      | 3  | 5  | 4  | 4  | 4  | 4  | 4  | 4  | 4  | 4   | 4   |
| 3                      | 3  | 4  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5   | 5   |
| 4                      | 4  | 5  | 4  | 4  | 5  | 3  | 5  | 4  | 4  | 4   | 4   |
| 5                      | 4  | 4  | 4  | 4  | 5  | 3  | 5  | 4  | 4  | 4   | 4   |
| 6                      | 4  | 4  | 4  | 4  | 5  | 3  | 5  | 3  | 4  | 4   | 4   |
| 7                      | 4  | 4  | 4  | 4  | 5  | 3  | 5  | 4  | 4  | 4   | 4   |
| 8                      | 5  | 4  | 4  | 4  | 5  | 4  | 4  | 4  | 3  | 4   | 4   |
| 9                      | 5  | 4  | 4  | 4  | 5  | 3  | 5  | 4  | 4  | 4   | 4   |
| 10                     | 4  | 4  | 4  | 4  | 5  | 4  | 5  | 3  | 4  | 5   | 4   |
| 11                     | 4  | 4  | 4  | 4  | 5  | 5  | 5  | 4  | 4  | 4   | 4   |
| 12                     | 4  | 4  | 4  | 4  | 5  | 4  | 5  | 4  | 4  | 4   | 4   |
| 13                     | 4  | 3  | 4  | 4  | 5  | 3  | 5  | 4  | 4  | 4   | 4   |
| 14                     | 4  | 5  | 5  | 4  | 5  | 4  | 5  | 4  | 4  | 5   | 4   |
| 15                     | 4  | 5  | 5  | 4  | 5  | 4  | 4  | 4  | 4  | 4   | 4   |
| 16                     | 4  | 5  | 3  | 4  | 5  | 4  | 5  | 5  | 4  | 4   | 4   |
| 17                     | 4  | 5  | 4  | 4  | 5  | 4  | 5  | 4  | 3  | 4   | 4   |
| 18                     | 5  | 4  | 4  | 4  | 5  | 3  | 5  | 4  | 4  | 3   | 4   |
| 19                     | 4  | 4  | 4  | 5  | 5  | 4  | 5  | 5  | 4  | 4   | 4   |
| 20                     | 4  | 5  | 4  | 5  | 5  | 5  | 4  | 4  | 3  | 4   | 4   |
| 21                     | 4  | 4  | 4  | 5  | 5  | 4  | 5  | 4  | 4  | 4   | 4   |

Table 9-4 Trend of feedbacks from the participants.

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<sup>14</sup> Technophobia is a term of psychology that reflects the fear or dislike of advanced technology especially computers. The symptom will be more obvious and complex when devices require more actions from the users. This often leads users refuse to continue using technologies.

## 9.4 Result and discussion

In this chapter, we evaluated our system using two steps of usability tests in CW and a real user participation survey. As can be seen from the first part of actions evaluation, most of the actions have achieved the expectation of the initial objective except actions “c”, “g” in Task1 and “b” in Task 2. The issues in Task1 can be addressed by enhancing a visible "help" sheet that tells visitor to interact with AR before proceed to the next step, and calling the QR Code function automatically after action “f”, while issues in Task 2 can be resolved by changing the nametag on the button. For questions evaluation, although three walkthrough questions in Task1 appear to have issue with respect to the usability problem, the first walkthrough question (Task1, Q2) will be redefined once action “c” has been improved. With the continuous growth of technology, we believe that the second walkthrough question (Task1, Q7) could also be resolved in the near future. For the third walkthrough question (Task1, Q9), even though the visiting history could assist curators to identify visitor’s behaviours, the presentation of these information to visitors is less useful for the visitors themselves.

For the result of real user participation, Table 9-5 displays the total scores for each question from the participants. With a maximum possible score of 105 (21\*5), all questions received a score of over 80 of satisfaction. Question 5 obtained the highest score, followed by questions 7 and 2. Although question 6 has the lowest score with only two-thirds of users satisfied with the semantic recommendation (responding with a scale  $\geq 4$ ), by enriching the metadata of the ontology we would be able to increase the accuracy of the recommended results.

| <b>NO.</b> | <b>Questions</b>                                                                                                 | <b>Total Score</b> |
|------------|------------------------------------------------------------------------------------------------------------------|--------------------|
| <b>01</b>  | Do you agree that the system provides a user-friendly interface for new users without training?                  | 85                 |
| <b>02</b>  | Did you find it easy to access the collection information?                                                       | 90                 |
| <b>03</b>  | Did you think the virtual assistant could trigger your learning interest?                                        | 87                 |
| <b>04</b>  | Can you find the recommendation button easily?                                                                   | 88                 |
| <b>05</b>  | Did you think the interactive quiz dialogs could help you to target the collections that are of interest to you? | 103                |
| <b>06</b>  | Did the recommendation results provide you with the desired collections?                                         | 80                 |
| <b>07</b>  | Was it easy to point the camera in front of the QR Code?                                                         | 99                 |
| <b>08</b>  | Did the 3D Map offer useful assistance for navigating your way?                                                  | 86                 |
| <b>09</b>  | Did you find it difficult to reach the recommended objects?                                                      | 83                 |
| <b>10</b>  | Were you satisfied with the interface of the application?                                                        | 86                 |
| <b>11</b>  | Were you satisfied with the overall experience after exploring the application?                                  | 85                 |

Table 9-5 Total score of each question (the full score of each question is 105).

Table 9-6 shows the distribution of scores for each question. As can be seen from the table, 19 out of 21 participants in question 5 agreed with the statement that the new way of interactivity provided by our framework allows users to explore potential collections of interest. For question 7, 16 users expressed total satisfaction (a score of 5) with the QR code presentation, indicating that the integration of digital devices and on-site environment have been addressed adequately. Although in question 6, 7 users suggested that the recommendation results could have room for improvement, the overall experience indicated in question 11 reported a good degree of satisfaction with no score under 4. In summary, the set of questions related to interface design received highly favourable responses with very few scores below 4 (Q1, Q2, Q4, Q5, Q10). The same is true for the integration effect between digital technology and on-site environment (Q3, Q7, Q8). We believe that the question related to the system recommendations (Q6) will improve with the

enrichment of data collection in the back-end database.

| Question<br>Score | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | Q11 |
|-------------------|----|----|----|----|----|----|----|----|----|-----|-----|
| 1                 | -  | -  | -  | -  | -  | -  | -  | -  | -  | -   | -   |
| 2                 | -  | -  | -  | -  | -  | -  | -  | -  | -  | -   | -   |
| 3                 | 2  | 1  | 1  | -  | -  | 7  | 1  | 2  | 3  | 1   | -   |
| 4                 | 16 | 13 | 16 | 17 | 2  | 11 | 4  | 15 | 16 | 17  | 20  |
| 5                 | 3  | 7  | 4  | 4  | 19 | 3  | 16 | 4  | 2  | 3   | 1   |

Table 9-6 Distribution of score in each question.

Overall, after two usability tests and a user survey, it can be stated that the prototype that implemented the proposed framework and theory has met the research expectation. Interestingly, while several usability issues appeared in the first two usability tests, some of them did not appear in the real user participation survey. For example, the participants can still find the recommended collections easily although the test identified the usability issue in Task1, Q7. For the after visit experience, even though Task1, Q9 did not pass the first test, the overall experience (Q11) still received a score of satisfaction with no score under 4 from the majority of participants.

# 10. Conclusions

## 10.1 Summary of the research output and contribution

Although digital technology has been applied much more extensively in cultural institutions such as museums and art galleries in recent years, very little work has been done on exploring the aspects of on-site interaction and visit personalization. With this research, we have taken this opportunity to raise the issue even more widely by evaluating a system from different perspectives with concern about the digital visualization, museum education, on-site interaction, proactive personalization, and diverse repacking in both physical museums and art galleries. We have proposed an approach to exploit personalized museum tours suiting different visitors' interests using semantic technology, and to link several enabling techniques such as VR, AR, and QR Code with on-site tours based on an interactive and dynamic user front-end interface. In this research, the PETTA system was developed under the proposed framework and evaluated by two systematic usability tests and a real user participation survey. The positive results and feedbacks received from these evaluations not only answer and support the research questions and hypotheses, but also confirm the value of our novel contributions in this field.

The research presented in this thesis is focused on creating an effective platform using existing digital technologies to connect cultural institutions such as museum and art gallery with their patrons in a highly personalized, interactive manner.

Through this approach, the connection between the experiences of visitors, curators, and administrators is clarified. From the walkthrough results and user feedbacks, it is clear that a digital framework that consider the factors of Visualization, Education, Interaction, Personalization, and Repacking will enhance visitor experience, and extend the time of art appreciation in on-site museum visit.

## 10.2 Result

In the introduction to this thesis we have defined several questions that guided this research. These questions have been addressed in different chapters within the thesis. Below we provide a summary.

For the first question:

5. *Do existing museum electronic devices have enough capability to meet end-user requirements for interaction and personalization in comparison with the fast growth of other similar information technologies?*

According to the survey done on the top 100 museums presented in chapter 5, unfortunately, there is still no approach that adequately addresses both the factors of interaction and personalization in the current implementations of on-site museum mobile devices.

For the second question:

6. *Are there specific concepts and frameworks based on interaction with the physical environment that can contribute to the understanding of roles for visitors, curators, and collections?*

As indicated from the literature review done on museum digitization from

several major organizations and iconic research projects in chapter 3, most of these projects concentrate only on the visitor's aspect, whereas the curator's and collection's viewpoints are largely ignored.

For the third question:

7. *Is there any current inference engine available for the museum setting to make semantic recommendations?*

According to our field survey of Semantic Web in chapter 4, several inference and recommendation techniques have been developed or suitable for cultural settings, such as the museum specific ontology CIDOC-CRM, the Java platform rule engine Jess, and the free open source Java framework Apache Jena.

For the last question:

8. *If so, how to integrate semantic framework and portable platform for understanding visitor's behaviour?*

From chapter six to eight, we have introduced and illustrated in detail regarding the framework and system implementation involving a portable front-end user interface and back-end semantic database for recommendation. The system usability tests and real participants evaluation conducted in chapter nine allow us to understand how visitors' behaviour can be detected and enhanced during on-site art appreciation.

### 10.2.1 Reflection

The results and outcomes of usability tests and final user evaluation validated the research hypotheses that we developed in the introduction section. First, by



carefully consider the fifth dimension (Behaviour) of IxD, the factors of two-way interaction and personalization can be implemented by museum electronic devices. Second, through implementing a prototype from the theoretical concept, and verifying its functionality by two rounds of usability tests, we showed that the combination of semantic inference and AR can be achieved in on-site museum exhibit. Finally, the user feedback also indicated that the value of cultural heritages can be increased significantly by museum digitization using an SOA structure. By following this structure, the system is able to collate with various components for seeking the maximum benefit to visitors, museum authorities, and collections.

### 10.2.2 Limitation

With the limited time and resources, a number of limitations are identified, which affect the final outcome of this research. For example, the amount of digitized collections recruited in the prototype might impact the result of recommendations and the accuracy of personalized suggestions. The condition of the collection itself also restricts the recommended outputs, as some fragmentary or antique museum collections may provide incomplete and defective information. Another limitation is the lack of real museum participation, as the final user survey was conducted under a simulated museum environment with limited number of participants. Therefore, the survey result may not truly reflect different types of museum environments, and the possible integration issues between the prototype and actual museum management systems. However, the contributions that we have made are still significant in terms of its novel solution and unique insight provided.

## 10.3 Future work

The work presented in this research is unique in the scope of digital curation especially in the museum area. The proposed framework and theory have been validated with respect to its positive value and functionality. However, more work

need to be done to bring the system to a stage suitable for real world deployment. In order to refine the recommendation result, more collections need to be included to the database. For the enhancement of after visit experience, the visit data needs to be transformed into a comprehensible description and presented to the visitor as a personalized feedback when they finished their journey. We believe that once the framework and prototype can be consummated and deployed into current museum operation, it will reinstate and reinforce the original role of museum. Emerging smart digital technologies that enhance interaction, such as automated facial expression recognition and emotion understanding, will bridge the gap between the digital space and physical space and take the museum visit experience to a new level not possible before. By that time, the statement of ICOM about museum will not be just a metaphor to convince people to explore on-site collections; instead, museum will act as a smart learning center to make heritages truly fit in people's life.

# Appendix1

**AG** = Audioguide

**CO** = Cost

**ED** = Education

**IN** = Interaction

**MS** = Multimediaguide/Smartphone application

**PE** = Personalization

**VI** = Visualization

The italics are the museums which are not included in the original list of TOP 100 ART MUSEUM ATTENDANCE published by The Art Newspaper(Paulo et al., 2013).

| NO  | Name of Museums                               | AG | MS | CO  | ED      | IN          | PE      | VI |
|-----|-----------------------------------------------|----|----|-----|---------|-------------|---------|----|
| 001 | <i>Palace Museum- CN</i>                      | Y  | -  | R   | -       | A           | L       | -  |
| 002 | Musée du Louvre- FR                           | Y  | Y  | R/P | K/r     | A/O/d/p     | L/f/i   | -  |
| 003 | The Metropolitan Museum of Art- US            | Y  | Y  | R/F | r       | A/O         | L       | -  |
| 004 | British Museum- UK                            | Y  | Y  | R/I | K/Q/W   | A/M/O/d/s/v | L/b/g/i | -  |
| 005 | Tate Modern- UK                               | Y  | Y  | R/P | K/V/r   | A/s         | L/b     | -  |
| 006 | National Gallery- UK                          | Y  | Y  | R/P | V       | A           | L       | -  |
| 007 | Vatican Museums- VA                           | Y  | -  | R   | -       | A           | L       | -  |
| 008 | National Palace Museum- TW                    | Y  | Y  | R/F | G/K/S/T | A/C/O/d/s   | L/b/i/k | -  |
| 009 | National Gallery of Art- US                   | Y  | Y  | R/F | K       | A/O         | L/i/k   | -  |
| 010 | Centre Pompidou- FR                           | -  | Y  | F   | K/V     | A/s         | -       | -  |
| 011 | Musée D'Orsay- FR                             | Y  | Y  | R/P | G/K     | A/M/O/s     | L/e/f/i | -  |
| 012 | Victoria & Albert Museum- UK                  | -  | Y  | F   | K/r     | A/O         | -       | -  |
| 013 | National Museum of Korea- KR                  | Y  | Y  | R/F | S/r     | A/O         | L/i     | -  |
| 014 | The State Hermitage Museum- RU                | Y  | Y  | P/I | D/K/V   | A/O/s       | L/b/i   | -  |
| 015 | <i>Museo del Prado- ES</i>                    | Y  | Y  | R/P | K/U     | A/X/s       | L/b/i   | -  |
| 016 | Museum of Modern Art- US                      | Y  | Y  | F   | K/r     | A/O/h/s     | L/b/i/k | H  |
| 017 | The National Folk Museum of Korea- KR         | Y  | -  | R   | -       | A           | L       | -  |
| 018 | Museo Nacional Centro de Arte Reina Sofía- ES | Y  | Y  | R/F | K       | A/E/s       | L/i     | -  |
| 019 | CCBB (Rio de Janeiro)- BZ                     | -  | -  | -   | -       | -           | -       | -  |
| 020 | National Portrait Gallery- UK                 | Y  | Y  | R/P | K/V     | A/O         | L/f     | -  |
| 021 | Shanghai Museum- CN                           | Y  | -  | R   | -       | A/O         | -       | -  |
| 022 | National Museum of Scotland- UK               | -  | Y  | F   | K       | O/s         | i       | -  |
| 023 | Galleria degli Uffizi- IT                     | Y  | Y  | R/P | K/r     | A/M         | L/b/i   | -  |
| 024 | <i>National Museum of Anthropology- MX</i>    | Y  | -  | R   | -       | A           | L       | -  |
| 025 | The Moscow Kremlin- RU                        | -  | -  | -   | -       | -           | -       | -  |
| 026 | National Galleries of Scotland- UK            | -  | Y  | F   | G/K/V   | M/s         | b       | -  |
| 027 | The J. Paul Getty Museum- US                  | -  | Y  | F   | K/V/r   | A/O         | b       | -  |
| 028 | National Gallery of Victoria- AU              | -  | Y  | F   | K       | O/s         | -       | -  |
| 029 | Tate Britain- UK                              | -  | Y  | F   | T/V     | A/s         | -       | -  |

|     |                                        |   |   |     |       |         |         |   |
|-----|----------------------------------------|---|---|-----|-------|---------|---------|---|
| 030 | Le Grand Palais- FR                    | - | Y | F   | V     | -       | L       | - |
| 031 | Tokyo National Museum- JP              | - | Y | F   | K/r   | s       | L/b/i   | - |
| 032 | State Tretyakov Gallery- RU            | - | Y | R   | -     | A       | -       | - |
| 033 | Van Gogh Museum- NL                    | - | Y | F   | -     | A/p/s   | L/k     | - |
| 034 | Queensland Art Gallery/GoMA- AU        | - | Y | F   | V     | O/s/q   | -       | - |
| 035 | FAMSF- US                              | Y | - | R   | -     | A       | -       | - |
| 036 | The Art Institute of Chicago- US       | Y | Y | R/F | K     | A/O/M   | L/f/i   | - |
| 037 | Saatchi Gallery- UK                    | - | - | -   | -     | -       | -       | - |
| 038 | Pergamonmuseum- DE                     | Y | - | R   | -     | A       | L       | - |
| 039 | Gyeongju National Museum- KR           | Y | Y | R/F | S/r   | A/O     | L/i     | - |
| 040 | Palazzo Ducale- IT                     | Y | Y | R/F | S     | A/M/O/s | i       | - |
| 041 | Musée du quai Branly- FR               | Y | Y | R/F | K/V   | A       | L       | - |
| 042 | Institut Valencià d'Art Modern- ES     | - | Y | F   | K/V/r | d/s/p   | b/f/i   | - |
| 043 | MMCA (Seoul)- KR                       | - | - | -   | -     | -       | -       | - |
| 044 | El Museo Thyssen-Bornemisza- ES        | Y | Y | R/F | K     | A/B/s   | L/i     | - |
| 045 | SAAM/Renwick- US                       | Y | - | F   | -     | A       | -       | - |
| 046 | Galleria dell'Accademia- IT            | Y | Y | R/P | K/r   | A/O/M   | L/b/i   | - |
| 047 | CCBB (Brasília)- BZ                    | - | - | -   | -     | -       | -       | - |
| 048 | Royal Academy of Arts- UK              | Y | - | R   | -     | A       | -       | - |
| 049 | Art Gallery of New South Wales- AU     | - | Y | F   | K/V   | A/M/s   | b/e     | - |
| 050 | Parco del Castello di Miramare- IT     | Y | - | R   | -     | A       | L       | - |
| 051 | Guggenheim Museum- US                  | - | Y | F   | K/V/r | A/O/s   | L/b/e/i | - |
| 052 | LACMA- US                              | - | Y | F   | K/V   | a/M/s   | f       | - |
| 053 | Palazzo Reale- IT                      | - | Y | F   | K/T/V | v       | -       | - |
| 054 | The Russian Museum- RU                 | Y | Y | R   | K     | A/O     | L       | - |
| 055 | The Belvedere- AT                      | Y | - | R   | -     | A       | L       | - |
| 056 | Museu Picasso- ES                      | Y | Y | R/F | K     | A/O     | L/i     | - |
| 057 | The National Art Museum of China- CN   | Y | - | R   | -     | A       | -       | - |
| 058 | The National Portrait Gallery- US      | - | - | -   | -     | -       | -       | - |
| 059 | Mori Art Museum- JP                    | Y | Y | R/F | -     | A/s     | L/i     | - |
| 060 | Kelvingrove Art Gallery and Museum- UK | - | Y | I   | G/K/Q | A/O     | f       | - |
| 061 | Royal Ontario Museum- CA               | Y | Y | R/F | G/K/V | A/O/X/q | i       | - |
| 062 | Acropolis Museum- GR                   | - | - | -   | -     | -       | -       | - |
| 063 | Guggenheim Bilbao- ES                  | Y | Y | R/F | K/V/r | A/O/s   | L/b/f/i | - |
| 064 | Riverside Museum- UK                   | - | Y | F   | G/Q   | -       | -       | - |
| 065 | Museum of Fine Arts- US                | Y | - | R   | V     | A       | L/f     | - |
| 066 | The National Art Center, Tokyo- JP     | - | - | -   | -     | -       | -       | - |
| 067 | CaixaForum Barcelona- ES               | - | Y | F   | V     | -       | -       | - |
| 068 | CCBB (São Paulo)- BZ                   | - | - | -   | -     | -       | -       | - |
| 069 | Rijksmuseum- NL                        | Y | Y | R/F | V     | A/O/M   | L/b/f/i | - |
| 070 | The National Museum of Western Art- JP | - | Y | F   | K/V   | A       | L/i     | - |
| 071 | Palazzo Strozzi- IT                    | Y | Y | R/F | K     | A       | L/b/i   | - |
| 072 | Parco di Capodimonte- IT               | - | - | -   | -     | -       | -       | - |
| 073 | ACMI- AU                               | - | - | -   | -     | -       | -       | - |
| 074 | Castel Sant'Angelo- IT                 | Y | - | R   | -     | A       | L       | - |

|            |                                        |   |   |     |       |           |       |   |
|------------|----------------------------------------|---|---|-----|-------|-----------|-------|---|
| <b>075</b> | CaixaForum Madrid- ES                  | - | Y | F   | V     | -         | -     | - |
| <b>076</b> | Freer and Sackler Galleries- US        | - | - | -   | -     | -         | -     | - |
| <b>077</b> | Ashmolean Museum- UK                   | Y | Y | R/P | -     | A/O       | L/i   | - |
| <b>078</b> | Museum of Contemporary Art- AU         | - | Y | F   | K     | A/O/s     | b     | H |
| <b>079</b> | Philadelphia Museum of Art- US         | Y | - | F   | -     | A         | -     | - |
| <b>080</b> | Museo Soumaya- MX                      | - | Y | F   | K     | O         | -     | - |
| <b>081</b> | The Israel Museum- IL                  | Y | Y | R/F | K/V   | A/O/s     | L/b/f | - |
| <b>082</b> | Museu Nacional d'Art de Catalunya- ES  | Y | - | F   | -     | A         | L     | - |
| <b>083</b> | Musée de l'Orangerie- FR               | Y | Y | R/P | K/V   | A         | L     | - |
| <b>084</b> | Art Gallery of Ontario- CA             | - | Y | F   | K/V/r | A/O/s     | L/b/i | H |
| <b>085</b> | Melbourne Museum- AU                   | - | Y | F   | K     | s/c       | b     | - |
| <b>086</b> | Birmingham Museum & Art Gallery- UK    | - | - | -   | -     | -         | -     | - |
| <b>087</b> | National Gallery of Australia- AU      | Y | - | F   | -     | A         | -     | - |
| <b>088</b> | Hirshhorn Museum- US                   | - | - | -   | -     | -         | -     | - |
| <b>089</b> | Tel Aviv Museum of Art- IL             | Y | - | R   | -     | A         | L     | - |
| <b>090</b> | Palazzo Pitti- IT                      | - | Y | P   | K     | M         | i     | - |
| <b>091</b> | The Museum of Fine Arts (Houston)- US  | Y | - | R   | -     | A         | L     | - |
| <b>092</b> | MACBA- ES                              | - | Y | F   | K     | O/a/s     | i     | - |
| <b>093</b> | Kunsthistorisches Museum- AT           | Y | Y | R/F | K     | A/s       | L/i   | - |
| <b>094</b> | Neues Museum- DE                       | Y | - | R   | -     | A         | L     | - |
| <b>095</b> | Ullens Center for Contemporary Art- CN | - | - | -   | -     | -         | -     | - |
| <b>096</b> | Museo centrale del Risorgimento- IT    | - | - | -   | -     | -         | -     | - |
| <b>097</b> | Reggia di Venaria Reale- IT            | Y | - | R   | -     | A         | L     | - |
| <b>098</b> | Complesso del Vittoriano- IT           | Y | Y | R/F | K/V   | A/a/q     | L/b   | - |
| <b>099</b> | National Portrait Gallery- AU          | Y | - | F   | -     | A         | -     | - |
| <b>100</b> | Istanbul Modern- TR                    | Y | Y | R/F | K/V/r | A/O/s/t/q | L/i   | - |
| <b>101</b> | National Gallery of Ireland- IE        | Y | Y | F   | K     | A         | L/k   | - |
| <b>102</b> | Musée des Arts Décoratifs- FR          | Y | - | R   | -     | A         | L     | - |
| <b>103</b> | Gwangju National Museum- KR            | - | - | -   | -     | -         | -     | - |

A = Audio guide/ Podcasts  
 B = E-book based collection interaction  
 C = Cooperative ranking  
 D = 3D collections recreation video  
 E = Sound enhancement  
 F = Free  
 G = Interactive game/ collection hunter  
 H = History of collection visiting  
 I = In-App purchases  
 K = Collections information/ related knowledge  
 L = Multi-languages audio  
 M = Indoor/Outdoor Map navigation  
 O = On-site floor maps  
 P = Online purchases  
 Q = Interactive quiz  
 R = Rental  
 S = Storytelling introduction  
 T = Timeline of collections  
 U = Ultra-high image observation  
 V = Video authors/ collections/ exhibits introduction  
 W = Wikipedia supported  
 X = x-ray/Periscope viewing  
 Y = Yes  
 - = No

a = Augmented Reality supported  
 b = Collection bookmarking  
 c = Motion control interaction  
 d = 3D model interaction  
 e = Event alert  
 f = Fixed tours  
 g = Personal trajectory guide  
 h = Photo shooting  
 i = Multi-language interface  
 k = Audio guide for adult/ kids  
 p = Real world panoramic  
 q = QR Code supported  
 r = Collections retrieval  
 s = Social interaction  
 t = Microsoft Tag supported  
 v = 2D virtual environment

# Appendix2

You are invited to help Griffith students and staff with their research project by participating in a survey. The title of this research project is:

**“Digitization of Museum and Art Gallery: A Framework for Enhancing User Interactivity and Personalization in On-site environments”**

This is a research project being conducted by Richard Yu-Chang Li at Griffith University. Participation in this research study is voluntary. You may choose not to participate. If you decide to participate in this research survey, you may withdraw at any time during the survey. If participants decide not to participate in this study or if you withdrawal from participating at any time, you will not be penalized.

We will do our best to keep your information confidential. All data is stored in a password protected electronic format. To help protect your confidentiality, the surveys will not contain information that will personally identify you. The results of this study will be used for scholarly purposes only.

If you are an adult (> 18 years old) who visit museums or art galleries on a casual basis with no assumed technical experience and art background and is interested in participating in the survey, please RSVP this email for more information.

If you have any questions about the research study, please contact:

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School of ICT, Griffith University  
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# Appendix3

## Digitization of Museum and Art Gallery: A Framework for Enhancing User Interactivity and Personalization in On-site environments.

### INFORMATION SHEET

#### Research Team

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Tel: (07) 55528671  
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**Purpose of this study:** This study is a student research conducted at Griffith University to evaluate the effectiveness of the designed digital framework for enhancing on-site museum experience.

**What you will do in the study:** You will be requested to interact with a front-end system by following a series of information and recommendations that the system provided. A short introduction and instructions will be provided at the beginning of the operation. After the engagement, you will then be asked to fill a hard copy survey sheet related to the user experience aspect of the system.

**Participants:** Adults (> 18 years old) of both sexes who visit museums or art galleries on a casual basis with no assumed technical experience and art background.

**Time required:** The study will require about 10-15 minutes of your time.

**Benefits:** There are no direct personal benefits to you for participating in this research study. The study will allow the researchers to assess the effectiveness of the designed framework for enhancing on-site museum experience.

**Possible Risks:** No foreseeable risk is associated with this study.



**Confidentiality:** The information that you provided in this study will be handled confidentially. All survey responses will be de-identified and no identifying information will be included in any publications or other outputs arising from the research.

**Voluntary participation:** Your participation in the study is completely voluntary and you can withdraw from the research at any time without explanation or penalty.

**Payment:** You will not receive any payment for participating in this study.

**Collected data:** The data will be accessed and analyzed by the student researchers only, and stored securely in encrypted form in Griffith Research Storage System for two years from the beginning of the data collection. After that, the data will be destroyed.

**Questions / further information:** If you have any questions or require further information about this research project please contact a member of the research team: contact details are provided at the top of this form.

**The ethical conduct of this research:** All Griffith University research is conducted in accordance with the National Statement on Ethical Conduct in Human Research. If you have any concerns or complaints about the ethical conduct of the research project, please feel free to contact the Manager, Research Ethics on 3735 54375 or [research-ethics@griffith.edu.au](mailto:research-ethics@griffith.edu.au).

**Feedback:** There will be no feedback or report sent to you after the study. However, participants interested in the survey findings could email Richard at email: [liyuchang@gmail.com](mailto:liyuchang@gmail.com) to request a copy of the survey summary.

The conduct of this research involves the collection, access and/ or use of your identified personal information. The information collected is confidential and will not be disclosed to third parties without your consent, except to meet government, legal or other regulatory authority requirements. A de-identified copy of this data may be used for other research purposes. However, your anonymity will at all times be safeguarded.

For further information, please consult the University's this dataPlan at <http://www.griffith.edu.au/about-griffith/plans-publications/griffith-university-privacy-plan> or telephone (07) 3735 4375.

# Appendix4

## **Digitization of Museum and Art Gallery: A Framework for Enhancing User Interactivity and Personalization in On-site environments.**

### **CONSENT FORM**

#### **Research Team**

##### **Student Researcher:**

Mr. Richard Yu-Chang Li  
School of ICT, Griffith University  
Tel: 0412945492  
Email: liyuchang@gmail.com

##### **Senior Researcher:**

Assoc. Prof. Alan Liew  
School of ICT, Griffith University  
Tel: (07) 55528671  
Email: a.liew@griffith.edu.au

By signing below, I confirm that I have read and understood the information package and in particular have noted that:

- I understand that my involvement in this research will include interact with a front-end system and filling out a survey form;
- I have had any questions answered to my satisfaction;
- I understand the risks involved;
- I understand that there will be no direct benefit to me from my participation in this research;
- I understand that my participation in this research is voluntary;
- I understand that if I have any additional questions I can contact the research team;
- I understand that I am free to withdraw at any time, without explanation or penalty;

- I understand that I can contact the Manager, Research Ethics, at Griffith University Human Research Ethics Committee on 3735 4375 (or [research-ethics@griffith.edu.au](mailto:research-ethics@griffith.edu.au)) if I have any concerns about the ethical conduct of the project; and
- I agree to participate in the project.

|                  |  |
|------------------|--|
| <b>Name</b>      |  |
| <b>Signature</b> |  |
| <b>Date</b>      |  |

# Appendix 5

## DIGITIZATION OF MUSEUM AND ART GALLERY: A FRAMEWORK FOR ENHANCING USER INTERACTIVITY AND PERSONALIZATION IN ON-SITE ENVIRONMENTS

### QUALITY SCALE SURVEY

|                              |
|------------------------------|
| Name: <input type="text"/>   |
| Age: <input type="text"/>    |
| Gender: <input type="text"/> |

For each item identified below, circle the number 1 to 5 that best fits your judgment of its quality. Use the rating scale to select the quality number.

| Survey Item                                                                                                         | Scale            |      |   |   |                                           |
|---------------------------------------------------------------------------------------------------------------------|------------------|------|---|---|-------------------------------------------|
|                                                                                                                     | P<br>o<br>o<br>r | Good |   |   | E<br>x<br>c<br>e<br>l<br>l<br>e<br>n<br>t |
| 1. Do you agree that the system provides a user-friendly interface for new users without training?                  | 1                | 2    | 3 | 4 | 5                                         |
| 2. Did you find it easy to access the collection information?                                                       | 1                | 2    | 3 | 4 | 5                                         |
| 3. Did you think the virtual assistant could trigger your learning interest?                                        | 1                | 2    | 3 | 4 | 5                                         |
| 4. Can you find the recommendation button easily?                                                                   | 1                | 2    | 3 | 4 | 5                                         |
| 5. Did you think the interactive quiz dialogs could help you to target the collections that are of interest to you? | 1                | 2    | 3 | 4 | 5                                         |
| 6. Did the recommendation results provide you the desired collections?                                              | 1                | 2    | 3 | 4 | 5                                         |
| 7. Was it easy to point the camera in front of the QR code?                                                         | 1                | 2    | 3 | 4 | 5                                         |
| 8. Did the 3D Map offer useful assistance for navigating your way?                                                  | 1                | 2    | 3 | 4 | 5                                         |
| 9. Did you find it difficult to reach the recommended objects?                                                      | 1                | 2    | 3 | 4 | 5                                         |
| 10. Were you satisfied with the interface of the application?                                                       | 1                | 2    | 3 | 4 | 5                                         |
| 11. Were you satisfied with the overall experience after exploring the application?                                 | 1                | 2    | 3 | 4 | 5                                         |

1

# Appendix6

## HUMAN RESEARCH ETHICS COMMITTEE

### **ETHICAL CLEARANCE CERTIFICATE**

This certificate generated on 22-01-2015.

This certificate confirms that protocol 'NR: Digitization of Museum and Art Gallery: A Framework for Enhancing User Interactivity and Personalization in On-site environments' (GU Protocol Number ICT/18/14/HREC) has ethical clearance from the Griffith University Human Research Ethics Committee (HREC) and has been issued with authorisation to be commenced.

The ethical clearance for this protocol runs from 09-01-2015 to 31-01-2015.

The named members of the research team for this protocol are:

APro Alan Wee-Chung Liew

Mr Yu-Chang Li

The research team has been sent correspondence that lists the standard conditions of ethical clearance that apply to Griffith University protocols.

The HREC is established in accordance with the *National Statement on Ethical Conduct on Research Involving Humans*. The operation of this Committee is outlined in the HREC Standard Operating Procedure, which is available from [www.gu.edu.au/or/ethics](http://www.gu.edu.au/or/ethics).

Please do not hesitate to contact me if you have any further queries about this matter.

Rick Williams  
Manager, Research Ethics  
Office for Research  
Bray Centre, N54 Room 0.15 Nathan Campus  
Griffith University  
Phone: 07 3735 4375  
Facsimile: 07 373 57994  
Email: [rick.williams@griffith.edu.au](mailto:rick.williams@griffith.edu.au)

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