The Museum Explorer: User Experience Enhancement In A Museum

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ABSTRACT

A learner in an informal learning environment, such as a museum, encounters various challenges. After initial assessment, a set of methods were proposed that may enhance a learner's experience in a museum using computer aided technologies. The most important insight was the need to support the museum visitor in three phases of activity: prior to the visit, during the visit, and after the visit. We hypothesized that software tools that could help connect these three phases would be helpful and valuable supports for the visitor. To test and evaluate our hypothesis, a system called "The Museum Explorer" was built and instantiated using the collection in the Museum of Antiquities located at the University of Saskatchewan. An evaluation of the Museum Explorer was conducted. Results show that the Museum Explorer was largely successful in achieving our goals.

The Museum Explorer is an integrated solution for visitors in museums across the pre-visit, visit, and post-visit phases. The Museum Explorer was designed to provide a means to connect and transfer user experience across the major phases of a museum visit. For each phase of a visitor's experience, a set of tools was built that provides intelligent and interactive communication features. To assist visitors selecting artefacts to visit, a recommender system allows users to select a set of constraints. To better manage interactivity, features and functions were offered based on context.

A study was conducted with volunteer museum visitors. Results from the study show that the Museum Explorer is a useful support. Analysis of the usage data captured by the Museum Explorer has revealed some interesting facts about users' preferences in the domain that can be used by future researchers.

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List of Acronyms

RFID	Radio Frequency Identification.
HMD	Head-mounted Display
CCD	Charge-coupled Device
IrDA	Infrared Data Association
PDA	Personal Digital Assistant
IR	Infrared
GPS	Global Positioning System
LCD	Liquid Crystal Display
RF	Radio Frequency
TCP	Transmission Control Protocol
Ajax	Asynchronous java script and XML. It is a web development technique used on the client side to create asynchronous web applications.
UI	User Interface
PHP	Hypertext Preprocessor. It's a scripting language specially used for web development.
HTML	Hypertext Markup Language

Chapter 1

Introduction

A modern museum containing a vast range of collections may turn out to be an information hazard for visitors. Limited knowledge about exhibits restricts visitors from selecting the most interesting set of artefacts when planning a visit. To assist visitors inside and outside a museum; modern museums facilitate various types of support. The Virtual Museum is a popular method used to support viewing a museum's collection online. In addition, many museums have tour-guide systems that run on a hand-held device to provide support in a physical tour. A typical tour-guide system comprises two basic functionalities; first, it allows visitors to extract information about the object of interest and second, it helps a visitor to navigate inside the museum. How the information is processed or what constraints are considered while generating the information determines the type of system (Context/location aware system, recommender system). A context/location aware system takes the context/physical environment into consideration in the process of generating information for users. On the other hand, a recommender system depends on user model and empirical data to process information. From the user's point of view, intent and end result becomes more significant than the process to produce results. The museum visitor is interested in a quality experience as he or she prepares for a visit, tours through the museum, and reflects on the visit afterwards.

In this thesis work the intent was to address the information need of a visitor in a museum and offer an integrated solution that considers three phases of a visit; the pre-visit phase, the visit phase and the post-visit phase. To accomplish the task, a set of tools called the Museum Explorer were developed to address the information need.

Museum tours and computer-based visit assistants can be thought of as learning supports in an informal learning domain. The scope of research contributions in this informal learning domain may involve improving a visitor's experience by offering tools and features that connect a visitor's experience in various phases of a museum visit, greater control in setting up constraints for the recommender tool, increased interactive features between visitors and artefacts and fostering community engagement opportunities.

A museum is considered as an informal learning environment available for visitors to explore. In a museum, the visitor comes across exhibits and artefacts from various cultural and historical backgrounds. Each artefact has its own story that relates historical events and cultural depictions. The advent of modern technologies has encouraged researchers to develop innovative tools to enhance learner experiences in informal learning environments. The overall experience of visitors in a museum can be divided into three major phases. They are: pre-visit experience, visiting experience and post-visit experience. The pre-visit experience involves orientation and planning activities to gather ideas about the museum and its collection. The visiting experience is the phase that curators and researchers have long focused upon. It incorporates activities during the physical tour in a museum. Lastly, the post-visit experience consists of services that may encourage return visits and further participation in community activities related to the museum and its collections. In previous research projects, incremental approaches that aim to improve visitor experiences focus on only one or two of the three phases explained above. In my thesis work, a system is developed called the "Museum Explorer" that addresses the information needs of a visitor in all three of the above mentioned phases and offers an integrated solution that provides continuity in user experience across these three phases. To accomplish the goal, previous approaches were combined and a new approach was proposed that works as a bridge between different phases of a visit. The proposed approach offers greater levels of personalization while addressing individual needs. In addition, some new functionality in the form of features are introduced to enrich a visitor's experience in this domain.

A visitor in the museum domain may be considered from multiple perspectives. From a museum tour guide system developer's point of view, the visitor is a "user" who intends to use the system. Since museums are considered to be an informal learning environment, it is a reasonable approach to also consider the visitor as a "learner". Lastly, a visitor/user/learner can also be thought of as a "participant" in various dimensions. As a user, a person can participate in social context by simply using a system and allowing the system to share information. As a learner, participation would involve sharing of knowledge. So, a person in the museum domain can play various roles at different times or in different contexts. In this thesis, I have referred to museum visitors as a visitor/user/learner/participant based on context.

One hypothesis in my thesis work is that "Connecting user experience across the three major phases (pre-visit, visiting and post-visit) can improve the museum visitor's experience."

The virtual museum is a widely used tool that augments the pre-visit experience. Generally, it offers detailed online information about a museum and the artefacts it possesses. This allows a guest to be informed about the museum collection before a physical tour. A simple addition to browsing an online museum exhibit is a "Tour Planner". The tour planner offers a set of functionalities that allows an online visitor to construct or plan a list of artefacts that he or she may like to visit on a physical tour. It also assists visitors to optimally plan a visit based on their available time. This simple extension to virtual museum concept allows a visitor to connect the virtual tour with a physical one. Using bookmarking functionality, a visitor can create his/her list of favorite artefacts during a virtual tour and use the list to further explore artefacts during the visiting or post-visit phases. Providing a summary of activities during post visit phase may allow visitors to reflect upon and hence connect his/her pre-visit and visiting experience with the post-visit phase. Allowing a visitor to follow a previous visitor's trail will connect previous visitor's experience in three phases with the experience of a visitor in pre-visit phase. Thus, by building tools and functionalities we can provide an environment for visitors to connect and transfer user experience across three major phases.

In a physical or virtual tour, a visitor needs to choose artefacts to inspect from hundreds or even thousands of artefacts. Generally, artefacts are categorized and exhibited in groups based on their type and cultural origin. For instances, artefacts affiliated with early Roman civilization are likely to be clustered together. Moreover, sculptures originated from Roman civilization may appear as a sub-cluster. Similarly, inscriptions or paintings affiliated with Roman civilization may also appear in a sub-cluster. A growing trend in modern museums involves offering recommender systems operating on a handheld device.

A recommender system helps a visitor to choose artefacts from the vast collection. Current recommender systems use empirical data and behavior patterns of visitors to make assumptions about their interests. The Museum Explorer collects background information of visitors through a pre-visit registration/questionnaire process. In the recommender system three types of recommendations are offered: recommendation from a curator, recommendation based on personal interests and recommendation from visitors with similar characteristics or interests. In addition, there are refinement options in the recommender system. A user can further refine the recommendation based on types of artefacts or cultural origins. Multiple types of recommendation and refinement options empower a user to set constraints for the recommender system. Since, different recommendation types and refinement options allows a user to select different set of constraints; it is expected that their preferences and choices will allow us to predict a general pattern in future visitors' behavior. Can we make more accurate assumption about behavior of users in this domain by answering the question "How do more personalized recommendations from preferences of other visitors compare against a curator's or expert's recommendation?"

A method often used to enhance user experience in a museum is to offer increased interactive features. How can one increase the interactive nature of a museum tour guide system? The method we adopted to increase the interactive nature of the Museum Explorer was by incorporating various features and functionalities that allow two way communications between the visitor and the system. Tools such as a Tour Planner, a mechanism to follow patrons who

previously visited and a Post-Visit Summarizer help a visitor acquire dynamic information from the system. Features such as artefact recommender and Search for Artefacts offer multiple level of interactivity. In addition, social computing functionalities such as endorsements, comments/annotations and bookmarking may encourage visitors to participate in social activities.

An abundance of choices may introduce the classical technology problem of feature bloat. A learner may become reluctant when faced with excessive technology [1]. Considering the museum as an informal learning environment; visitors may become perplexed with an abundance of alternative system choices. So, it can be an interesting research question to explore: "How much interactivity is appropriate in a museum tour guide system?" In other words, how can a designer best manage interactive features to achieve optimum results?

The post-visit experience of a museum visitor is mostly overlooked in museum systems and in the museum literature. It is an important part of the overall experience of a visitor. So, the question becomes "How can we enhance the post visit experience of a museum visitor?" Offering the ability to reflect upon their experience can be the most useful method to encourage a visitor to come back. Offering some kind of quick access to favorite artefacts can be useful. Allowing visitors to play the role of an expert user through endorsement, comment and bookmark functionalities can also enhance a visitor's experience in the post-visit phase. In this thesis work, effectiveness of the above-mentioned functionalities was evaluated to determine what contributes to enhancing the overall experience of a visitor in museum.

The basic purpose of this thesis work is to address information needs of a museum visitor in various visit phases. Approaching this problem, one should determine the information needs of a visitor first. A system called Museum Explorer was built address this need. While designing the system, the following principles were taken into consideration:

- Build tools that connect user experience across three major phases.

- Allowing maximum user control and personalization in the recommender system
- Provide interactive features and functionalities to enhance user experience.
- Improve visitor's experience in the post-visit phase.

Visitor experiences were divided into three phases and tools and features were built to support visitors across three phases. For the pre-visit phase, a tool called Tour Planner was built that helps a visitor to plan a visit based on available time and personal interest. To allow a visitor to explore the museum collection a lightweight intelligent recommender system was built. It uses empirical data, background information and behavior patterns to recommend artefacts for a visitor. To provide a greater level of control on user's side, multiple types of recommendation and various refinement options are available in the recommender system. A feature called Follow Patrons was included that allows a visitor to follow previous visitors' trails or paths. This also allows a visitor to share their experience with future visitors. Besides, functionalities such as endorsement, comment, bookmark and query were included with artefacts. This increases interactive nature of the system.

A search functionality is available to learn more about artefacts stumbled upon during the visiting phase. Also during the visiting phase features such as My Favorites, My Tour gives quick access to a visitor's favorite artefacts. Lastly, a Post-Visit Summarizer tool was included that summarizes a visitor's activity and allows him/her to reflect on the experience.

In summary, while considering the information needs of a visitor in a museum, several research questions were raised. The basic research question is "Can we improve visitor experience by providing various intelligent and interactive communication features?" To answer this question, a system called Museum Explorer was developed that offers a set of tools designed with a vision to enhance the visitor experience. A more focused research question is "can we connect user experience across the three major phases in an efficient manner? If yes, is it useful?" To offer greater control for users, a recommender system was build that offers multiple types of

recommendations and refinement options. It was an interesting observation analyzing behavior and preferences of visitors in this domain with the help of the answer to the question “How more personalized recommendations based on preferences of prior visitors compare to a curator’s or expert’s recommendation.”

A principal method for enhancing user experience can be achieved by providing increased interactive features. It is another noteworthy argument to explore that “How much interactivity is appropriate in a museum tour guide system?” In other words, how can we best manage the interactive features that may improve experience? The method adopted in Museum Explorer was to offer only the relevant features and functionalities in relevant phases. Lastly, the most ignored phase of visitor experience is the post visit experience. Tools and functionalities were offered in Museum Explorer during the post-visit phase that are expected to enhance user experience during post-visit phase. A study was conducted to determine how well methods incorporated in Museum Explorer achieved their design goals.

Chapter 2

Literature Review

The museum domain is an ideal informal learning environment where many projects have previously been carried out to support visitors in a technology-assisted way. Existing systems mostly place emphasis on helping visitors in one of the three major phases (pre-visit experience, visiting experience and post-visit experience). Unfortunately, none of them consider the relationship among all three phases and address them in an integrated way.

2.1 History of Museums

Italian aristocrats begun to collect artworks from ancient Greece and Rome during mid-15th century [2]; the primary purpose of such collections was to exhibit them in front of important guests. Exhibits gained greater interest about artworks with the mass population. As a result, people started collecting items from around the world. In 17th century, there were plenty of private collections in Europe. The purpose of collecting and exhibiting artworks changed gradually with time. Instead of upholding owners' social position, people started considering collections as owners' view, about the world. The purpose of displaying artefacts was broadened to exhibitions of an encyclopedic nature. Some of these collections were used by researchers in universities for teaching purposes, but mostly these collections were owned by individuals.

In mid-17th century, the Royal Society was formed in England with a vision to develop a shared language among tradesmen, scientists and the church. To support this cause, the Society gathered a collection of items, known as its repository, to physically represent the language. They

constructed an institution to own the collection. The idea behind formation of an institution was to create a better chance of surviving and growing while it belongs to an institution rather than an individual. A curator was also appointed by the Royal Society to manage the laboratory that was connected with the repository. At this time, the collection was only accessible to the member of the Royal Society; it was not open to public. The collection is a part of the British Museum now.

After the end of French revolution, the collections owned by aristocrats in society were acquired in the name of the new Republic. Collections were gathered, reorganized and transformed with an aim to make the collections available to all citizens. The nature of the content of collections changed from a three-dimensional encyclopedia of knowledge to less specific, changeable information. A similar perception was gradually adopted throughout the rest of Europe.

In the nineteenth century museum collections transformed to represent chronological records of the past. Despite the association of many presentation and grouping techniques, general practice remains the same today (a more detailed history of the evolution of museum can be found in [2] [3]).

Museums today are concerned with collecting, preserving and providing access to important cultural, artistic, historical and archaeological objects, with an intention to educate and inform general the public about those artefacts. Curators play an important role as they plan the arrangement, cataloguing and exhibition of collection. The advent of various technologies has shaped museums and offers a different dimension. Modern technologies are shaping museums towards technologically based interactive environment.

2.2 Current State of Using Technology in Museums

In recent years, various approaches have been adopted to assist museum visitors using technology. Information systems introduced into museums by researchers can be divided into

two major streams. They are: Recommender Systems and Context/location aware Systems. A recommender system uses various constraints affiliated with visitors, their preferences/ behavior/ activities, empirical data and so on. In the end, a recommender system produces a set of recommendations that matches visitor interests in a given domain. A context aware system can take the external environment into consideration and adapt its behavior accordingly. Systems that are called locations aware primarily take the physical location of the visitor into consideration to generate contextual responses. As discussed in previous chapter, visitors in a museum go through three major phases in their visit. After analyzing some previous works, it appears that the recommender systems and context aware systems developed for previous projects mostly work on one of the three major visit phases. Observation also suggests that a very little effort is carried out to address all three phases together. If three phases were addressed in one system, it could allow the visitor to connect and transfer user experiences before, during and after a visit. There are also systems that aim to address the user experience enhancement issue by offering a better audiovisual experience or better user interface. Systems highlighted in this section falls into one or more categories discussed above. In the following, several projects are elaborated following the chronology of their development.

In 1999, a collaboration project among ETH and University of Leuven produced two systems to assist visitors in a museum [4]. The first system facilitates virtual tour in an ancient Greek city 'Sagalassosa'. The city was destroyed by an earthquake in the 6th century. A three dimensional representation of the site in virtual space is presented to the visitor, accompanied with an animated tour guide. The guide looks similar to a mask on the screen. A visitor can interact with the guide using natural language (English or Dutch). The guide is capable of responding to queries such as: go to a place in the virtual city, or make a query about the city and objects shown on the screen. The guide acknowledges the visitors' query by a nod of the head if it understands the query; otherwise eyebrows are raised to indicate that the question needs to be asked again differently. Visitor gets a 'No' if the query does not make any sense in the current context.

The second ETH/Leuven system is a palmtop assistant that gives information about objects in which a visitor has shown interest [4]. The Museum of Fine Arts in Antwerp organized a painting exhibition on the 400th birthday of Antoon Van Dijck. A visitor can take a picture of a painting or parts of a painting from different angles; in response he/she receives detailed information about the photo. A camera connected to palmtop takes picture and sends it to a server. Once the picture is identified, corresponding information is sent back to the visitor. The system was built to address the issue of delivering information that interests the visitor. This was an attempt to build a personalized content delivery system.

In 2000, an integrated effort was taken by the Tokyo University Museum to address the use of digital technologies in museum to gather, preserve, research, exhibit and educate patrons about the collection [5]. A virtual museum was built realizing all the benefits of a digital museum. Some additional functionality was added to support interaction between visitors and the virtual space. Four interaction techniques were presented through an augmented-reality museum exhibition system.

- Personal Digital Museum Assistant is an information system where a visitor can retrieve detailed information about an exhibit by holding the PDA over it [5]. An IrDA tag is attached to every object and an IrDA tag reader is connected to the visitor's PDA phone. The visitor retrieves information about the exhibit interest by holding the PDA phone in front of the IrDA tag attached to the exhibit. The tag receiver attached to the PDA phone identifies the object and retrieves information from the server.
- Museum Augmented Reality information system allows a visitor to see detailed information about exhibits by looking into it wearing a special pair of glasses [5]. It uses an HMD equipped with a small CCD camera that captures object identities. This system combines the bar code method and the overlaid display using an HMD. This system enables visitors to obtain detailed information by only looking at the objects that they are interested in.
- Point-it is another museum information system in the Tokyo University Museum where visitors could use a leaser pointer to acquire detailed information about an exhibit on their PDA screen [5]. Inside the museum a visitor is accompanied by a simulated expositor.

When visitor approaches an exhibit, the expositor automatically gives overall information about the exhibit. If the visitor is further interested about the exhibit, s/he has to use the laser pointer to point it onto the title of the exhibit to get more detailed information about the exhibit.

- Real-world bookmarking was the fourth system the Tokyo University museum offered visitors. Visitors bookmark exhibits they are attracted to while visiting the museum and revisit their museum tour later on online [5]. A visitor carries an RFID card with them while visiting; the card holds information about visitor. When a visitor wants to bookmark an exhibit; s/he puts the card in front of the RFID reader attached to an exhibit. Later on the visitor can revisit exhibits s/he bookmarked online.

Besides interaction techniques stated in four systems developed in Tokyo University Museum, there was also a virtual museum built to assist visitors to explore the museum online [5]. Due to scarcity of space many materials are not displayed in real exhibitions. In virtual museum a visitor could see all elements. In a web browser, an avatar of the visitor is placed in the virtual environment. A visitor can control their avatar and explore the virtual environment. A multimedia presentation is given to the visitor explaining exhibits residing in the virtual environment. One special feature about this system is that a visitor can see other avatars in the virtual space. This may help a visitor to decide how many other people are interested in an exhibit. Visitors could also do voice chatting in this virtual museum.

In 2001, Point of Departure was launched in the San Francisco Museum of Modern Arts to address the need for an interactive tour guide system [6]. Multiple methods were tested to see what works best for curators and visitors in a museum. Two major techniques were: i) the iPAC Gallery Explorer and ii) a Smart Table. In the iPAC Gallery Explorer, video clips are presented to a visitor, which explains an artefact from the artist's point of view. It also explains six aspects of an artefact considered important as an outcome of their analysis. Using the Smart Table, a visitor can access hypermedia content explaining artefacts. The visitor can use their hands to interact with the smart table. The table has a motion detecting sensor attached to it to capture movement of hand. They also provide the visitor with an option to arrange artworks according to

their liking in a “Make Your Own Gallery”. They also allowed visitors to write comments about their selection to share them with future visitors.

Scotto Voss was another system deployed in the same year with Point of Departure at Filoli, a Georgian Revival house in Woodside, California [7]. Using this system a visitor can query every detail about objects located in an old house. It is a standalone application loaded on the visitors’ PDA. There are several photographs loaded on the PDA, where each of the photographs was taken facing one wall of a room in a historic house. By pressing a button, a visitor can change the currently displayed picture. The system does not automatically select the most appropriate picture but rather the visitor has to navigate to the most suitable picture in current context. When the visitor taps an object in a photograph, the system gives a description of the object. To help the visitor to identify objects that the system recognizes, the system displays an outline around each object identified by the system.

In 2002, a collaboration project between HP lab and a Science Museum in San Francisco addressed the information need of a visitor inside and outside the museum [8]. The museum consists of a large open-plan space populated with science exhibits. The system developed had two major components in it. The first part is a set of “informer tools”. Tools mentioned assists a visitor by providing information while traveling inside the museum. The second part is a “rememberer” tool that helps visitors to record and preserve experience inside the museum. A visitor points a PDA towards the object of interest to retrieve related information. Sensors in the PDA set detect the identifier attached to the object. Once the identifier is detected, it is converted to a URL using a resolution service. The URL is a request to a web server for a particular recourse. This technology is named “Physical Hyperlink”. From the user’s point of view, the process is similar to clicking a hyperlink and retrieving information. A visitor can also navigate through a list and retrieve information. This web-based system combines three basic functions: informing, suggesting and remembering. The system delivers a static webpage to the user’s PDA when they visit an exhibit. Every exhibit has its own homepage pointing to 4-16 links that

contains more detailed information about the exhibit. The visitor can bookmark a page, take pictures to associate it with an exhibit and eventually leads to create their personal scrapbook.

The museum wearable was introduced by the MIT Media lab in the year 2002 [9]. A unique real-time story telling device is incorporated with the museum visit. It uses a special type of device called "Private Eye" to deliver an audio-visual presentation in a real time surrounded view. The visitor carries a backpack on his/her shoulder, which accommodates a small computer. The system uses infrared communication to find the location of a visitor. The system incorporates a guide to evaluate the visitor's preference by observing their path and length of stops along the museum's exhibit space. The guide selects content from a large database of available movie clips, audio, and animations to show in "Private Eye". The Museum Wearable analyzes each individual considering their special learning needs or curiosity and offers a new type of museum experience claimed to be more entertaining and informative. The system offers visitors an experience more similar to immersive cinema than to the traditional museum experience. Museum Wearable has classified visitors in three types: *busy, greedy* and *selective* [9]. This has been selected as the predominant museum visitor types from the museum literature. It uses a custom-made infrared location sensor to gather tracking information about the visitor's path in the museum and uses this information to introduce evidence in a dynamic Bayesian network. The Bayesian network interprets the sensor information and delivers content to the visitor. It performs probabilistic reasoning under uncertainty in real time to identify the type of a visitor. After identification of the visitor's type it delivers an audiovisual narration to the visitor as a function of the estimated type, interactively in time and space. The model has been tested and validated on observed visitor tracking data using the [10].

INTRIGUE [11] is a prototype tourist information system introduced in the year 2003. The system supports tourists in the area around the city of Torino through desktop or mobile devices. It recommends sights to a user considering the preferences of heterogeneous tourist groups (such as families with children and elderly) and provides an explanation of the recommendations by addressing the group members' requirements. Beside site recommendations, the system provides

an interface to schedule a tour. A significant amount of effort has been devoted to extract information about the characteristics of the tourist attractions a visitor is interested in. The system offers a tourist catalog that can be browsed based on various criteria. Categorization of tourist destinations is carried out considering a diverse range of options. A visitor can search based on different viewpoints (such as: historical period, artistic current, types of monuments and so forth) or geographic locations. Using geographic location related search a visitor can narrow down the search to various sub areas. The system also has a functionality to generate dynamic pages encompassing tourist attractions. The page generation relies on rules dependent on metadata each item (tourist attractions) possesses. These strategies also support device dependent page generation to address the issue of supporting both handheld device and desktop computers. When a visitor requests to generate recommendations, the system considers preferences of the visitor and conflicting preferences of a heterogeneous group. For example, a user having a social-science background organizes a tour with some children and impaired persons. If he/she searches for the civil buildings in Torino area, the system displays a page showing preferences of the initial user (visitor) including suggestions for other visitors in the group. It gives a short explanation of the reason for selection of the list. For example, the following is a sample explanation: “For children, it is much eye-catching; it requires low background knowledge… For yourself it is much eye-catching and it has high historical value, for impaired . . . `` [ref 11, page 7]. There is an interactive agenda that facilitates the organization of itineraries. After random selection of a set of attractions, the system allows a visitor to further refine the search by specifying more constraints such as: day of visit, arrival/departure time and location, preferred time of visit (morning or afternoon). Based on the visitor’s choices, the system generates a suitable itinerary. In the presentation, the system specifies estimated transfer time to reach the attraction from the previous location, the time of the visit and the expected duration for each attraction. Presentation of information is different in desktop and handheld devices. In desktop all information is shown in one page; while with a mobile device, information is presented in two separate pages.

In 2004, first location aware fully operating system was deployed in Marble Museum of Carrara [12]. The application contained information about 150 artefacts. The system stores all

information in the local memory of a PDA where it takes about 225 MB space. It uses a map to help a visitor navigating inside the museum and presents information depending on several level of abstraction. They are: a museum map, a section map and each artefact of a section. Artefacts are indicated by icons in a map. A Text to audio speech software is integrated inside the system to generate audio clips corresponding to the text information. A visitor can start or stop an audio presentation, change its volume level and retrieve more detailed information. To Determine position of a visitor, an Infrared emitter is installed at the entrance of every room. An infrared beacon is installed at the ceiling of the building which sends a Unique ID to server using IrDA protocol. IR beacon covers ninety degree. Since there are several emitters in every beacon, it can cover the entire space. When a visitor enters into a new section, the application automatically provides a museum map to the visitor where the current section is highlighted. Afterwards, an audio presentation is given to visitor addressing main characteristics of the section and a map is provided later on indicating position of artefacts. A visitor can further refine their query by selecting an artefact from the map and retrieve more information about it.

Another location aware system was introduced in the year 2004 at Gallo-Roman Museum of Tongeren and the open air museum Bokrijk [13]. First museum is an indoor and open air museum where it gives a historic overview of the archaeological findings in the region. The second one is solely an open air museum that depicts life of farmers in the region 150 years ago. The system is named ImogI. It is a context aware mobile guide for outdoor as well as indoor locations. It works on GPS information in outdoor and communicates with other objects in the environment through Bluetooth. Two major contributions of this project are associating information with artefacts or objects instead of geographic coordinates and systems. At that time, most GPS information based system used to provide static information. It works well when the target object is stationary (e.g. buildings, tourist sites). In a museum, position of artefacts changes in every exhibition. So, they related information with the proximity of certain artefacts. Information can be obtained in two different ways. A visitor can access static information stored on the mobile guide or they can also query artefacts surrounding them and receive information through wireless communication. ImogI has three different interactive tools that can help to design, configure and use custom maps. Using the Desktop Design Tool, one can load a custom

map and annotate it with different information. Since, it is a generic solution for mobile guides, similar functionalities are supported on mobile interface through the Mobile Configuration Tool. They also have a Mobile Information System tool to give context aware navigational support.

"Real World Bookmarking" concept introduced in the Tokyo University Museum was implemented in an exhibition on the history of modern media six years later with a different name "Digital Backpacking in the Museum using SmartCard" [14]. A visitor can buy a SmartCard that enables them to store collected or self-created data in a 'digital backpack'. A visitor walks into the exhibition with only the smart card. There are several information terminals inside where visitor can extract relevant information and interact with the system using a smartcard. SmartCard is a REID chip embedded card which allows the system to uniquely identify a visitor. A visitor can bookmark objects, information he is interested in and later on can revisit them inside and outside exhibition. The system can identify objects of interest by: looking into the backpack of the visitor, considering the amount of time spent on each exhibit and the degree of interest shown by the visitor, examining the time interval between two exhibits, and so on. Thus, depending on the user model, the system recommends an exhibit the visitor may be interested in further exploring.

In 2007, the PEACH project (Personal Experience with Active Cultural Heritage) was deployed as an integrated framework for museum visit [15]. Various intelligent techniques were considered and assembled together into one system. Three major aspects of this system are: motivate visitors by using an animated agent throughout the museum visit and draw their attention using the agent, automatically generate video documentary on mobile device depending on the user model and lastly generating a post visit summary for every visitor depending on their behavior and choices during their visit in museum. PEACH was implemented in the Buonconsiglio Castle in Trento, Italy. When the visitor approaches the entrance tower of the castle, s/he finds a large plasma screen. The interior of the castle is painted with famous Fourteenth Century frescoes representing the Months of the Year with scenes of towns, nature, and daily activities that would have occurred during each month of a year. A PDA set with

infrared capability is provided to visitor to facilitate interaction with system and determine his position and orientation near exhibits. As visitor enters into the castle, animated characters on the plasma screen introduces them and provides a general description of the site. Visitor selects a character from the plasma screen and the character disappears from the big screen and appears in the PDA screen. During the visit, system shows presentations about details of frescoes that the visitor seems interested in. Presentations include multimedia documentaries built dynamically and adaptively according to the visitor's interests, as derived from his behavior or explicitly communicated. Observation and analysis of behavior includes stops at exhibits of similar kind, time spent in front of an exhibit, and presentations the visitor has been exposed to and so on. A visitor can express his/her degree of liking towards current presentation. A visitor can make query about exhibits by taking a picture using the PDA. Picture is automatically transmitted to the system where it recognizes visitor's focus and provides additional specific presentation about focused area. The PEACH System provides information tailored for individual need. It acknowledges activities previously performed by visitors. At the end of the visit, a report is generated and delivered to the visitor underlying exhibits the visitor were interested in and makes suggestions for future.

In 2009, two collaborative models were developed to predict behavior of a visitor inside the museum. A computer-supported methodology was used to gather data about visitor's pathway in Melbourne Museum, Australia. The obtained dataset was used to validate two models. Visitors' viewing times of unseen exhibits were predicted from their viewing times at visited ones. Models proposed were 1) nearest-neighbour collaborative filter [16] based on memory and 2) A model-based approach utilizing the theory of Gaussian spatial processes [17]. The proposed models were tested using data gathered previously. Two separate systems (GECKOtracker and GECKOvisualiser) [17] were developed in this project. GECKOtracker [17] is used to track behavior of a visitor inside the museum. GECKOvisualiser [17] is used for post-collection visualization and analysis of the gathered data.

In 2009, CHIP (Cultural Heritage Information Personalization) project were deployed at the Rijksmuseum Amsterdam [18]. The Goal of this project was to explore interactive and engaging ways to acquire visitors' interest in a museum collection, provide personalized museum services both online and inside the museum and link visitors' experiences online and inside the museum. They constructed a unique approach to link user experience online and inside the museum. Systems built previously were allowing visitors to bookmark artefacts, generate automatic report about the museum tour and allowing visitors to access museum collections online. In CHIP, a visitor can plan his tour online. Activities performed online are monitored closely to provide personalized information inside the museum and make useful recommendations both online and inside the museum. In a typical scenario, a user creates his tour plan based on recommendations provided by the CHIP Artwork Recommender. Inside the museum, a visitor can follow the same tour created online or can also start a new tour. During the visit, the tour is dynamically adapted depending on the interests and preferences shown by a visitor. The navigation path, the length of the tour and the number of artwork offered are also adapted accordingly with the dynamic adaptation. Interaction with the mobile guide during the museum visit is dynamically synchronized with the user profiles maintained on the CHIP website. To support personalization in several levels, CHIP has three tools. They are: Online Art Recommender, Online Tour Wizard and Mobile Museum Guide. The Online Art Recommender helps a visitor to explore artworks of their interest online and associate them with their own user profile. The Online Tour Wizard generates online tours containing artworks a user may be interest about depending on their user profile. Lastly, the Mobile Museum Guide is a tool that helps a visitor inside the museum by providing extensive description about the museum. It can adapt with the dynamic behavior of the visitor and respond accordingly. The Mobile guide offers various level of adaptation (e.g. location, temporal preferences and art interests). To incorporate above functionalities, the system filters out artworks that do not satisfy the current user model of the visitor and subsequently add up artworks that match with the current model. Lastly, calculate the optimal navigational path for the visitor. The guide also considers both implicit and explicit contextual information. Time spent per artwork, monitoring user position is implicit contextual information and user rating, maximum number of artwork or maximum amount of time user wants to spend are explicit contextual information. At any point of the tour, visitor can change some interesting parameters in tour configuration level. For example, a visitor can ask the system to adapt the number of

artworks to see in a tour based on the amount of time s/he wants to spend or s/he can ask the system to adapt time to be spent based on the number of artworks s/he wants to see. A visitor can follow a friend's path or s/he can ask the system to generate a tour depending on several friends' path.

A recent trend in the museum domain is to construct games focusing on the principles of the educational design and the use of mobile technology. Use of mobile technologies for educational purposes in museums can be classified into three main categories. The first category includes applications that deliver information to the visitor as multimedia and context-related content. The second category includes applications that attempt to improve and enhance the interaction between users and exhibits. The third category includes applications targeting children aged 5-15 challenging them to complete some pedagogical tasks. Two games developed to create specific educational-game scenarios were Donation [19] and Museum Scrabble [19].

"Donation" [19] is a group activity that intends to engage children in collection and manipulation of information about the museum exhibits. Here children are asked to study an exhibit in order to help somebody to donate a new artefact to the museum. Children receive information about exhibits using their mobile phones. The RFID tags attached with artefacts help them to detect relevant artefacts and collect hidden hints. Teams of children may exchange hint phrases to encourage collaboration. Participants need to point their mobile phone towards an exhibit to check if it is the exhibit they are looking for. This activity is completed once both teams point to the correct exhibit.

Museum Scrabble [19] is a game based on the idea of linking exhibit properties with other exhibits. There are three basic components in this game. They are the clues, the triggers and the exhibits. Pieces of textual information used to link a specific exhibit to other exhibits are called "clues". A link may contain varying strengths. Thus a team is motivated to collect stronger links to achieve more points. Some information about an exhibit is stored in the game as items/triggers

of the relevant clue. Each trigger can be linked with several exhibits giving points to the player according to its relevance to the trigger. A more relevant trigger adds more points to the score than less relevant ones. A player can choose any clue from a given list of clues. He/she has the freedom to link it to a trigger or may keep it for another trigger. Once an exhibit is linked to a trigger, it is no longer available for another group. One group can see its rival group's progress and links to various triggers. The game ends when all clues are linked to exhibits and the team with highest score wins the game. The system provides some basic information about a set of key exhibits and engages students to use this information as a point of view for searching for other relevant exhibits. The educational aim of this project is to help students focus on specific information about a set of key exhibits, think about this information analyzing them based on reasoning and use their imagination and their skill to observe as tools for searching and finding relevant exhibits in the museum.

In 2011, the PIL project [20] introduced a new proximity-based indoor positioning system at the Hecht museum keeping the constraints of a museum into consideration. It provided accuracy within 1.5 to 2 meters. Since there is no commonly acceptable indoor solution for proximity positioning, the one proposed in this project minimizes installation complexity while providing acceptable accuracy in locating an object of interest. The Hecht museum used a Radio Frequency (RF) based positioning system relying on a wireless sensor network composed of RF devices. They are: fixed RF tags called Beacons, small mobile wearable RF tags called Blinds and RF to TCP Gateways. The Gateways routes the data reported by both the Blinds' and Beacons' status, to the PIL's server. Beacons are statically located at near relevant locations of interest in the museum as well as on the entrance and exit path. Blinds are carried by visitors. When a Blind approaches towards a Beacon or another Blind, it reports this information to the PIL sever through the nearest Gateway. The PIL server analyzes that information to determine the visitor's position. Another PIL component initiates the process of personalization of content based on given location. At any given point of time, a Blind may receive signal from several Beacons. Several numbers of possible locations may be reported this way. The system has several interesting features: (i) measuring proximity among Blinds and reasoning about proximity among visitors; (ii) detecting voice level and activity (iii) detecting orientation of visitors using

magnetometers (iv) detecting motion using embedded accelerometers. Particular attention was paid to power consumption of battery powered devices (Beacons), to their dimension (Blinds) and to the best match of proximity areas.

The Science Foundation of Ireland funded a project (in the year 2011) that focused on developing a system that offered three dimensional representation of information on the virtual space [21]. Primary goal of this project was to produce high quality 3D experience for visitors at a very low cost. A visitor needs to carry a laptop and a pair of active shutter LCD glasses to access the system. The idea of providing audio visual information in this project is similar to Museum Wearable [9]. The Museum Wearable has a location and context aware information delivery system. On the other hand, the current one is strictly virtual museum that focused on accurate reconstruction of the National Museum of Ireland's archaeology building in the virtual space. Information retrieval on this system is a self-motivated process; suggestions/recommendations are not available. A 3D modeling of rooms was performed on wired mesh drawing. 50 photographs were taken at random locations throughout the exhibition to draw the wired mesh with the help of Autodesk's Imagemodeller [22]. An open source game engine Unity [23] was used to create the 3d interactive environment. Audio visual information was integrated at this point. Lastly, proper lighting conditions were applied. NextEngine desktop 3D laser scanner was used to scan artefacts. Finally, Nvidia 3D vision system was used to provide the 3D visual experience. The system can be configured to use with both LCD active shutter glasses (currently expensive) and red/cyan passive 3D glasses (cheap).

A project funded by the National Science Foundation USA approached the user experience enhancement problem by introducing tabletop games that helps visitors to learn about evolution [24]. The experiment was carried out on the Harvard Museum of Natural History. It is observed that the games designed for learning had limited success [25]. The goal of this project was to develop iterative tabletop exhibits for museums that encourage visitors to engage for prolonged period of time. A total of 80 user groups (30 families and 50 social groups) used the tabletop game. The usage data was taken into consideration for evaluation. To help visitors learning about

evolution, a multi-level puzzle game called Build-a-Tree (BAT) is designed. The game asks a visitor to construct trees showing evolutionary relationships of organisms. Organisms are presented with black silhouettes superimposed on colored circles that visitors can drag around the table. Touching any two circles together will join them into a tree. This same mechanism can be used to join organisms onto an existing tree or to join two sub-trees together. There are options that allow a visitor to removes an organism from an existing tree. The techniques discussed above also supports collaborative interaction as multiple players can work together, dragging and connecting organisms simultaneously. A spring physics model is used to animate construction and deconstruction of trees. There are seven levels available in this game. Each level becomes increasingly difficult with progression of one. To evaluate the work, the Active Prolonged Engagement [22] technique was used. Results suggested that visitors were engaged in interaction with exhibits for a prolonged period of time. Therefore, it is claimed in this project that the interaction techniques were successful in expanding users'/visitors' interest.

In AMARA (The Affective Museum of Art Resource Agent), a unique recommendation method is presented [26]. The project was carried out on the platform of the Indianapolis Museum of Art website. Recommendations are produced based on choices of answers given by users (answer to multiple choice questions). A total of 318,810 social tags were collected from various sources and determined 5,160 reoccurring social tags. Above tags were connected with questions and answers designed on six dimensions (background, identification, theme, association, emotion and figure). Interaction from the system is conducted by simple questions such as his/her current feelings, preferences and interests in artworks. Predetermined social tags are associated with each available answer to the multiple choice question. At the end of questionnaire session, artworks associated with highest number of social tags will appear on top of the recommended list. It is a unique approach to assist visitors with little to no previous knowledge about museum collection and arts.

The InterFaces project implemented at the Museum of Science, Boston aimed to increase interests and engagement of middle school students in science and technology [27]. A virtual

museum was created that allows visitors to interact with artefacts using natural language. Two virtual photorealistic characters are created (Grace and Ada) that allows a visitor to interact and acquire information in a conversation. Operator presses the push-to-talk button and speaks into a microphone to interact with characters. The natural language processing unit comprises three modules. The audio clip recorded by the audio acquisition client is sent to the Automatic Speech Recognizer (ASR). The ASR creates hypotheses of the words that were said, and then sends the text to the Language Understanding Module. The Audio Speech Recognizer module uses the SONIC toolkit [28]. The Language Understanding module uses a statistical text classification algorithm to generate responses based on given texts. A set of responses is produced using a domain-specific library of scripted responses. The response set is passed to the Dialogue Management Module. After checking recent dialogue history, response set is used to select one response from the response set. Thus, it ensures that the given response is appropriate in current context. The Dialogue Manager has a mechanism to handle interruption. It sends one sentence at a time to the animation component. If any interruption is occurred by the visitor; next sequence of responses are processed. Thus, the natural language is processed and a context aware response is generated. The InterFaces offer a highly interactive and entertaining experience to visitors.

2.3 Analysis of Technology Supports in Museums

The projects discussed above are some of the most notable recent contributions in museum related research. Systems developed in the late nineteen nineties were confined to many extents due to the limitation of technology. Hand-held devices (smart phones and tablets) are used as tools to support visitors inside a museum. Smart phones (called PDAs in 90s) were expensive and fairly rare. Supports offered by PDAs in the nineties were also very limited. Projects mentioned from the nineties were the earliest attempts to integrate museum and technology. Systems systems and approaches cited above fall into one or more categories mentioned in the opening paragraph of this section. Table 1 illustrates the visit-phase categories into which these systems fall. Notice that no one system addresses all three visit-phases.

The projects carried out at the Tokyo University museum came closest to addressing all three phases of a visited. The projects presented a number of different subsystems with different interaction techniques to retrieve detailed information about artefacts [5]. Personal Digital

Name of Systems	Supported Phases		
	Pre-Visit	**Visiting**	**Post-Visit**
collaboration project among ETH and University of Leuven	Yes	No	No
System Developed For the Tokyo University Museum	Yes	Yes	Yes
	Five systems were built. Not Integrated		
Point of Departure	Yes	No	Yes
Scotto Voss	No	Yes	No
A collaboration project among HP lab and a Science Museum in San Francisco	No	Yes	Yes
Museum Wearable	No	Yes	No
INTRIGUE	Yes	Yes	No
Tour Guide System at the Marble Museum of Carrara	No	Yes	No
ImogI	No	Yes	No
PEACH	No	Yes	Yes
GECKOtracker/GECKOvisualiser	No	Yes	No
CHIP	Yes	Yes	No
Donation	No	Yes	No
Museum Scrabble	No	Yes	No
PIL	No	Yes	No
The project by the Science Foundation of Ireland	Yes	No	No
AMARA	Yes	Yes	No
InterFace	No	Yes	No
Educational guide at the Harvard Museum of Natural History	No	Yes	No

Table 1: List of systems and supported phases

Museum and Point-it are very similar type of sub-systems considering the end result, although the underlying technology behind each was different. The first one uses IrDA and the other uses lasers to detect the object of interest. An IrDA receiver attached to visitor's PDA automatically detects the nearest object and produces detailed information. On the other hand, a visitor has to point his/her PDA set towards the exhibit to retrieve detailed information while using Point-it. The Museum AR sub-system provides a better multimedia support by offering audio visual representation of information wearing a special glass. The Real world Bookmarking sub-system system allows a visitor to bookmark exhibits and access them during the post visit phase. Beside above mentioned interaction techniques, they created a virtual museum to replicate the virtual representation of the existing museum. In this project, although the information needs of a visitor in three major phases were addressed, the functionalities offered for different phases were divided into five different sub-systems. Integration of the sub-systems was not fully considered.

Two interaction media (PDA and smart table) were tested in the Point of Departure [6]. Notable features offered were to create a personal gallery and write comment about artefacts. Point of Departure addressed the user experience enhancement issue by offering two interaction media. It offered features to assist visitors during pre-visit and post visit phase. No feature was available to personalize information based on individual need. The idea to address the post-visit experience was introduced by the option to create a personal gallery.

The Scotto Voss [7] was a simple PDA based application that assists a visitor during the visiting phase. There is no functionality available in the system that produces dynamic information. A collaboration project among HP lab and a Science Museum in San Francisco first made a conscious attempt to address visiting and post visit experience of a visitor by offering them informer and rememberer tool [8]. It also incorporated an effective recommendation system.

Museum Wearable [9] is a location aware personalized content delivery system that introduced an innovative device called "Private Eye" for audio visual representation of information. It also

focuses entirely on visiting phase. No effort was allocated to address issues related to pre-visit or post-visit phase. INTRIGUE [11] supports a visitor in pre-visit and visiting phase. In pre-visit phase, it offers tour-planning facilities. During the visiting phase, various types of refinement options are available to make the recommendation more useful. Its ability to address both individual and group needs is a unique attribute.

The system introduced at the Marble Museum of Carrara is one of earliest attempt in building location aware systems [12]. In addition to the navigation support it provides contextual information. This system works entirely on the visiting phase. The pre-visit and the post-visit phase is been overlooked. ImogI is another location aware system that offers context aware user interface [13]. A notable feature is that it can work both indoor and outdoor. The system administrator can configure a map to place objects or connect information with available objects. ImogI also works on the visiting phase. No feature is built targeting pre-visit or post-visit phase.

PEACH (Personal Experience with Active Cultural Heritage) was introduced in 2007 as a framework that addresses the information need of a visitor during the visiting and the post-visit phase [15]. It has an animated agent that accompanies a visitor during the visiting phase to guide them inside a museum. It comes with a decent recommender system to support visitors inside a museum. Analyzing the behavior of a visitor, the system generates a video file that incorporates detailed audio visual presentation of objects a visitor is interested about. Video clips are generated and presented while a visitor progress through his/her museum visit. The contribution made for the post-visit phase was remarkable. It produces summary of activities for a visitor. So, it is a context/location aware system that works on both the visiting and the post visit phase.

The system developed for the Melbourne Museum in Australia is mainly a recommender system [17]. The goal of that project was testing some collaborative model to predict a visitor's behavior more accurately. The recommender system developed on that project was targeted to assist

visitors during the visiting phase. Besides, GECKOtracker was used to track users inside a museum to provide location aware information.

The CHIP (Cultural Heritage Information Personalization) project was another notable attempt to address the information need of a visitor during pre-visit and visiting phase. For the pre-visit phase, it facilitate tour planning and online museum. A tour is generated based on existing user model. Visitor can add time constraint to it. For the visiting phase, it allows a visitor to follow the planned trip. The recommender system built to assist visitor during visiting phase can adapt to user behavior in run time. With the help of tour planning tool, it allows a visitor to connect a visitor's experience from the pre-visit phase to the visiting phase. There is an option to bookmark artefacts. Bookmarked artefacts can be viewed later. It is not claimed that the functionality is included to address the information need of a visitor during the post visit phase.

Targeting informal learning prospect in the museum domain, many games were developed. Donation [19] and Museum Scrabble [19] and the tabletop game at Harvard Museum of Natural History [24] are brighter example from that trend. These games are developed for encouraging a learner in museum to explore deeper. A general observation about the gaming approach is that the effort is entirely targeted towards the visiting phase. No effort is devoted towards the pre-visit and the post-visit phase. Games are designed to encourage visitors to learn about certain things. Usually no recommendation features are available there. Therefore, they are not been considered as an affective tour guide.

PIL project [20] was another location aware content delivery system. Enhancement of indoor positioning system was main focus of this project. They were largely successful in developing a method that has an accuracy range from 1.5 meter to 2 meter. Here again, the focus was entirely on the visiting phase. It provides location aware information to visitors during the visiting phase. The pre and the post visit phase have been overlooked.

The project funded by the science foundation of Ireland focused on developing a virtual museum that offers 3D experience to visitors in a very low cost [21]. It offers support only during the pre-visit phase. Exploration of information is a self-motivated process; recommendation features are not available.

AMARA (The Affective Museum of Art Resource Agent) is a recommender system that uses social media tags to relate them with an existing art collection and a questionnaire set to determine user interests [26]. Recommendation features offered by AMARA can be used on both pre-visit and visiting phase. Personalization of recommendation is done with the help of the questionnaire set.

InterFace offers interactive features to visitors to enhance user experience. Two photo realistic characters are used to promote interactivity. A visitor can use speech to communicate with the system. In response, a contextual reply is given in natural language. The project is centered on offering a better interaction method. No recommendation feature is available. It works on the visiting phase. Pre-visit and post visit phase has been overlooked.

Each of above mentioned projects have made unique contributions in museum related research. Categorizing them based on visitor's experience phase; we see that that they work mostly on the visiting phase of user experience. Pre-visit and post visit experience is less investigated. Context-aware personalized content delivery, location-aware systems, and an excellent recommender system are examples where lots of effort is given to address information needs of a visitor in the visiting phase.

2.4 Prospects for Future Research

In my research work, I make an effort to show the significance of user experience in pre-visit and post-visit phases along with the visiting phase. An integrated solution is proposed that addresses the three major phase of user experience. In contrast with previous works, the notion of enhanced interactive features is introduced as a method to improve the user experience. A general observation about previous works on location aware, context aware or a recommender system focuses primarily on what information to deliver. From the user's perspective, useful information is highly desirable. Alongside useful information, an interactive and intelligent system can further augment the user experience. A recommendation feature is another useful feature offered in most museum tour guide systems. Functional processes of a recommender system involve ordering a set of elements based on given constraints. In a typical scenario, an intelligent recommender system generates a set of elements that is considered to be the best selection in given context. So, the recommender system uses a set of constraints to order elements into a sequence. In my proposed solution, a user can choose a set of ordering constraints that suits his/her interests (various recommendation types and refinement options). I believe that adding a customization facility within a recommender system can further enhance the user experience. Besides, this process can help to track user behavior that could result in improvement of the recommendation process.

Lastly, post-visit experience is mostly overlooked in previous projects. In a few occasions, I noticed that a facility to create a visitor's favorite collection is given. In addition to a favorite list, several other methods should be incorporated to improve user experience in post-visit phase. For instance, engagement in some sort of "community of user" activities or summarizing one's visit in a story-telling manner may further enhance the user experience in this phase.

Chapter 3

System Design: The Museum Explorer

The basic purpose of this research is to the enhance visitor's experience in a museum using computer-aided technologies. In previous sections, several research questions in this domain were identified. Consequently, previous attempts to improve user experience in a museum were elaborated. To address our hypothesis, a system called "The Museum Explorer" was built to assist visitors in all three phases of a museum visit.

3.1 Approach

While designing the system, information needs of a visitor in various phases have been considered. The primary question outlined in previous sections was "Can we improve museum visitor experiences providing various intelligent and interactive communication features?" The implied question becomes "What features should the system offer? What functionalities need to be incorporated to acquire the desired end result?" The Museum Explorer system was built to satisfy the information needs of a visitor in pre-visit, visiting and post-visit phases. Tools are required to connect the three major phases of a visitor's experience while taking a museum tour.

For the pre-visit phase, a tour planner can be the most useful tool. In Museum Explorer, the Tour Planner is a platform that facilitates planning a physical tour based on individual preferences. This tool allows a visitor to transfer his/her experience from pre-visit to the visiting phase. Allowing visitors to follow a previous visitor's trail is another useful addition to the pre-visit

phase. By allowing a visitor to explore a previous visitor's trail, it may open up new opportunities discovered by previous visitors.

The primary challenge for a visitor in a museum is to select artefacts from an abundance of choices. The Museum Explorer contains a recommender system. To improve the recommendation feature, users need the ability to select the set of constraints they want to impose to get suitable recommendations. A recommended artefact set can be derived based on various constraints. It is useful to have multiple types of recommendations. Moreover, refinement options to filter and sort artefacts according to their cultural origin and artefact types may offer greater control to users. Using refinement options, one can receive recommendations on selected subset of artefacts. The addition of multiple dimensions to the recommendation system satisfies information needs of various user groups.

For the visiting phase, searching for artefacts by name can be a very useful feature. While taking a physical tour, a visitor may become interested in a particular artefact. Searching for information about artefacts by name allows the visitor to acquire detailed information about the artefact. Lastly, a feature to reflect on the visit allows a visitor to connect the experience of the post visit phase with previous phases. A summary record of the activities carried out by the visitor up to that point may be useful.

The tools mentioned above assist in managing information about artefacts that may be relevant to a visitor. But besides this information each artefact has its own identity and a vast amount of information can be associated with each artefact in a museum. In addition to the database of static information about an artefact, each artefact can also be connected with each prior visitor. Endorsements (positive/negative), comments, bookmarks add to the information about an artefact and provide a permanent connection between visitor and artefact.

Enabling endorsements, comments, queries and bookmarks can be useful in various ways. First, they will enrich metadata associated with the artefact. Second, visitors will be able to see the opinion of previous visitors about the artefact. Third, it will allow the recommender tool to judge the popularity of that artefact. Lastly, it will provide a mechanism for previous visitors to provide their expert opinion and possibly stay connected after the visit.

An attempt to connect user experience across three major phases may be considered as the largest contribution in this domain by this project. To connect the three phases, certain tools and functionalities have been offered. Considering pre-visit and the visiting phase, a visitor needs a platform to plan the tour and follow it through during the visiting phase. The Tour Planner tool may offer that functionality to plan a tour and follow it during the visiting phase. Besides, while taking the virtual tour; artefacts explored can be bookmarked and added to the favorite list. Artefacts added to the favorite list can be added to the tour at any time during the pre-visit phase. Tour planner tool and the bookmark functionality certainly allow a visitor to transfer his/her pre-visit experience into the visiting phase. The post-visit summarizer tool may provide summary of activities carried out by the visitor. This allows a visitor to recall and revisit his/her experience of the pre-visit and the visiting phase during the post-visit phase. A Follow Patrons feature allows a visitor to access other visitor's activities. Considering visitor experience as a lifecycle chronologically, it ends at the post-visit phase. The follow patrons feature may provide a scope to recycle previous visitors experience from post-visit phase to the new visitor's experience at the pre-visit phase. Hypothetically, this establishes a link from post-visit phase to the visiting phase. Besides, other interactive functionalities such as endorsement (positive/negative), comments, and query may also contribute towards connecting various phases of user experience.

"Recommendation of artefacts" is generally the most important component in a museum tour guide. As previously emphasized, the primary challenge a visitor faces in a museum is finding artefacts that interests him/her. The multidimensional approach taken to address the recommender may offer greater level of control from visitor's prospect. In the Museum Explorer,

three types of recommendations are offered. The first is the curator's favorite list called “Recommendations from Curator”. The second type is based on previous visitors’ behavior yielding popularity “Recommendation from Visitors”. Lastly, “Recommendation from Similar People” may suggest a list that comes from people having similar background and interests as the visitor. If we generalize the above recommendation types, the first one is the expert’s suggested list. The second one is people's popular choice list and the last one is a friend's suggested list. It was expected that a usage pattern about preferred recommendation type would be revealed among different user groups.

Shedding light on the post-visit phase, lots of new ideas could be introduced. Due to the scope of this project, this was not fully explored. The focus of my work was devoted to allowing the visitor to act as an expert in this domain during the post visit phase. The question becomes “How do we allow a visitor to act as an expert?” A simplistic approach would be to make interactive functionalities affiliated with artefacts available to visitors during the post-visit phase. Functionalities may refer to endorsement, comments, bookmarking and query. Opinions expressed by a visitor during the post-visit phase may be considered as expert’s opinion. From the visitor’s point of view, this allows a visitor to stay connected and play a role after the visit. Tools such as Post-visit Summarizer, My favorite, My Tour and Search for Artefacts were built to enhance user experience during the post-visit phase. The Post-Visit Summarizer allows a visitor to revisit his/her experience. My Tour and My favorite tool give them a quick access to objects of interests. The Search for Artefacts tool gives the visitor access to the existing collection.

The abundance of functionalities may lead to apprehension towards learning a new technology. If all functionalities discussed so far are presented together; learning how to use the system may appear to be challenging. This raises the question “How to better manage the interactive features?” Since, the visitor’s experience is already divided into three segments (pre-visit, visiting, post-visit); the relevant functionalities associated with only one phase at a time are accessible. This should minimize the number of tools offered at one time. For instance, during

the visiting phase, a user has already decided about what s/he wants to see. At that point, offering the Tour Planner tool or Recommender tool will be irrelevant. The only useful tools during the visiting phase should be My Tour and Search For Artefacts. My Tour allows a visitor to follow through with the tour already planned. Search For Artefacts tool facilitates a visitor to retrieve detailed information about artefacts that caught their attention during the visit.

For the pre-visit phase; Tour Planner, Follow Patrons, Recommender, My favorites, My Tour, Refinement options for recommendations and Search For Artefacts would be relevant functionalities. The Recommender tool allows visitors to explore the virtual museum collection. The Follow Patrons feature exposes previous visitor's experience. My Tour and My Favorites tool provides quick access to the visitor's favorite list. The Search For Artefacts tool allows a visitor to run a search on the full museum collection.

Post-visit summarizer, My Tour, My favorite and Search For Artefacts functionalities are considered to be relevant for the post-visit phase. By dividing relevant functionalities and offering those in groups should reduce the complexity of the system and its interactive features.

3.2 System Design Principles

When the system was designed, the behavior of the system was determined depending on the goal of this project. In addition to achieving goals, the system designed is expected to be platform independent, modular, and reusable. It should also offer a static user experience.

To make the system platform independent, a web based system has been developed that provides an identical interface for mobile device, tablet, laptop and desktop. One advantage of having a web based system is that the operating system or platform of the client machine becomes irrelevant. It offers identical performance for all types of client machine. An open source php server was used on the server side. The Ajax framework has been used to transfer data between

client and server to provide a consistent user experience. It is, when the user interface is updated; only the part that contains something new is been updated. It does not refresh the whole page. Thus, it offers a user experience similar to a desktop based application.

All functionality of the system shall be in php classes. This makes the design and functionality to exist in separate domains. In order to make a system modular and reusable, multiple layer of abstraction were introduced. Various functionalities performed by the system are carried out with a set of functions belonging to php classes.

The system was designed with four layer of abstraction. The four tier architecture in figure 3.1 offers layer of abstraction and modularity from developer's point of view. First two tiers (user interface and ajax components) resides on the client side. The last two (PHP Classes and Database) exists on the server side. The user interface is a collection of empty div boxes (HTML

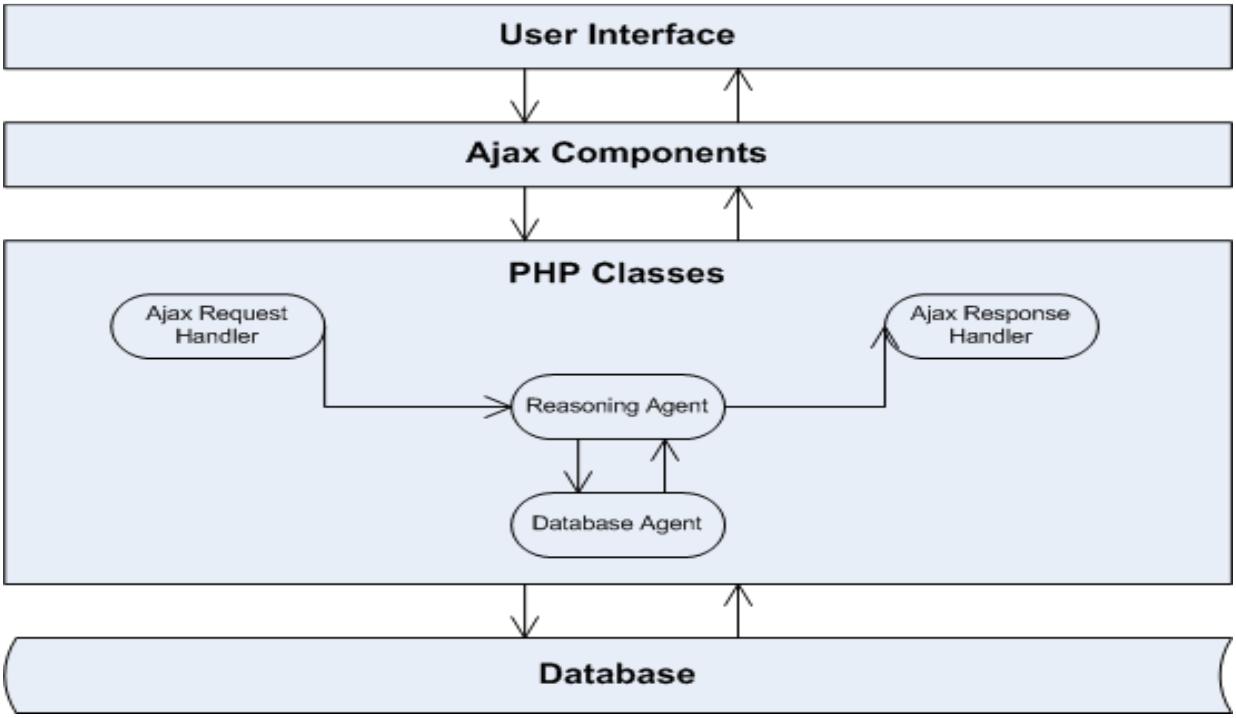

Figure 1: Four tier Architecture

tags) that is populated during runtime. The ajax components are collection of javascript functions that is called with an onclick event triggered from the user interface. In the third tier, there are three more layers. Ajax Request Handler class on top initially handles requests from the client side (ajax components). Once the service request type is determined, it calls the reasoning agent. Reasoning Agent carry out the analytical work needed to complete the task. Any incoming or outgoing request towards database is handled by the database agent. Mostly, the database agent is called by the reasoning agent. Once the request is processed, result is sent to the ajax response handler. Ajax response handler does the formatting of the result and returns it back to the client. Ajax component on the client side render the acquired information on the user interface. In figure 1, data flow of the system is shown focusing the four tier architecture.

Thus, a task is carried out from UI to Ajax component to Ajax Request Handler agent to Reasoning Agent to Database Agent and backwards. The above mentioned layers of abstractions improve modularity of the system. If a certain part of the system needs a fix it does not affect other parts of the system. A developer only needs to update portion of that layer of the system. Thus, introducing multiple layer and agents improve the modularity of the system. It also allows a developer to include features in an incremental approach. Museum Explorer was developed following incremental approach. Features and functionalities were added incrementally. Due to the design and architecture of the system; it could be done with a very little additional effort.

3.3 Use Case

A typical use case scenario would start with a visitor registering into the Museum Explorer system. A user registration is a three step process. Frist, the Museum Explorer requires a visitor to select a unique user id and password. In next step, it prompts a user to answer questions related to basic user information, educational background, political or philosophical affiliation and work information. Lastly, a visitor specifies his/her cultural interests and interests about artefact types. Once the registration process is completed, it takes a user into a logged in state. It is expected that a visitor will follow through with typical phases a museum visitor experience while taking a museum tour. There are different set of functionalities offered in different phases.

By default, a user is assigned to the pre-visit phase after logging into the system first time. But, a user can change his /her phase at any time. Typical user behavior is assumed to follow phases as pre-visit, visiting and post-visit phase chronologically (figure 2).

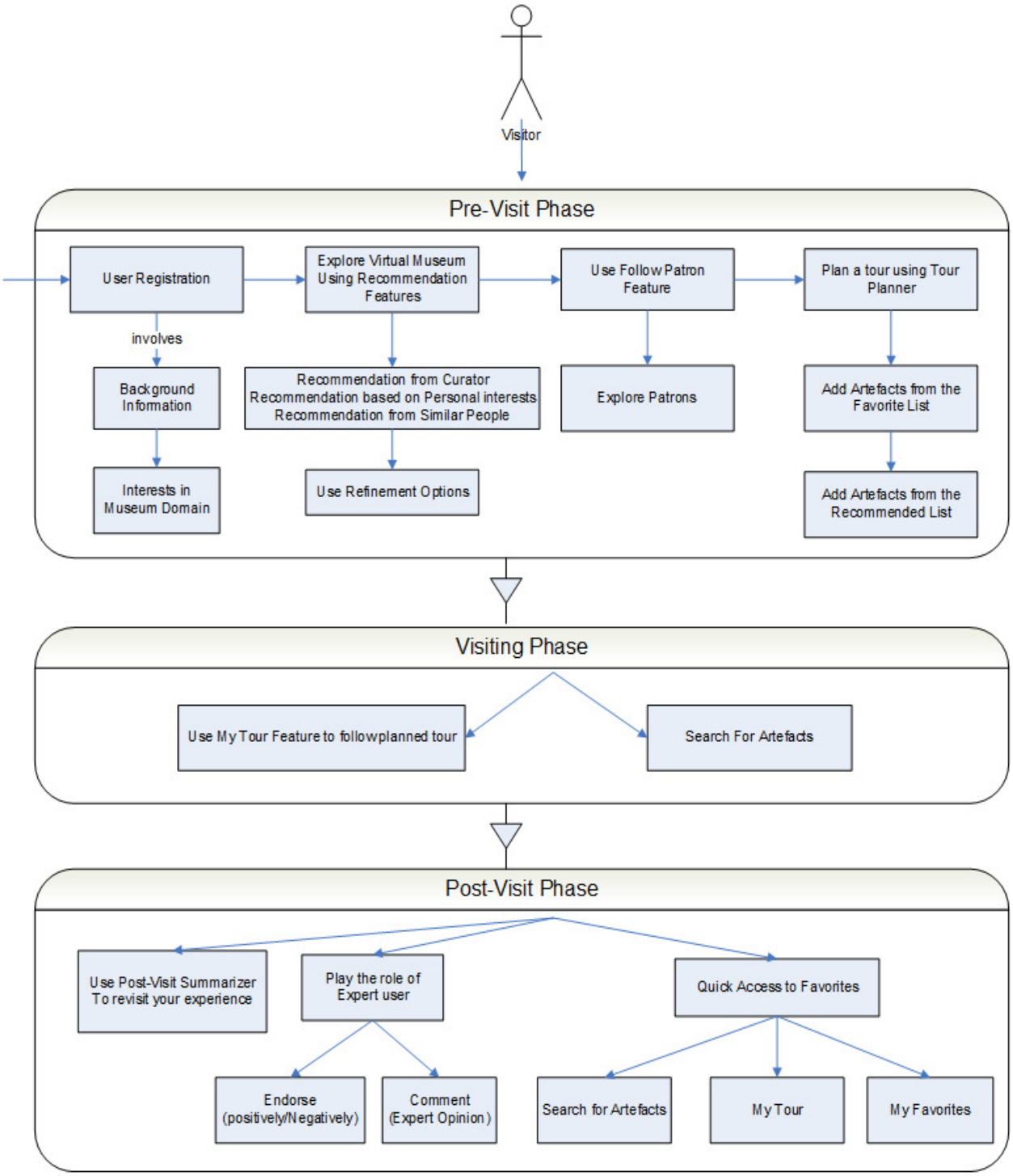

Figure 2: Use Case Diagram

Figure 2 reflects a typical scenario of using the Museum Explorer. The arrows in the diagram are not meant to limit possible sequences, but rather to show typical sequences. In fact, any sequence of steps shown in the diagram can be skipped and the user can go back and forth as desired. To avoid complexity, a simplified diagram is provided.

During the pre-visit phase, a user may use the recommendation features to explore the virtual museum. Once the virtual museum is explored, follow patrons feature can illustrate the experiences previous visitors had while taking a museum tour and using the Museum Explorer. At this point, a visitor is expected to have his/her favorite list and enough usage data for the system to better predict his/her behavior. So, using Tour Planner would be the last step a visitor is expected to carry out during the pre-visit phase. After the tour is planned, a visitor may take the physical tour at his/her convenient time. During the visiting phase, only My Tour and Search For Artefacts feature is offered. So, a visitor may follow through the tour that was planned or they can search for a random artefact that drawn his/her interest. Please check the figure 2 for a typical scenario.

With the completion of the physical tour, a visitor enters into the post-visit phase. In post-visit phase, four features are available. A visitor has quick access to the favorite list, tour, and search for artefacts feature. Besides, post-visit summarizer would be another tool that would allow a visitor to revisit his/her experience. There is a navigation box on the top right corner that allows a user to switch phases. Discussion above portrays typical behavior of a museum visitor. Steps discussed above also elaborate the optimum use of the system. The figure 2 explains steps that are discussed above.

3.4 System States

The Museum Explorer goes through various states. Primarily there are four major states. They are: User Registration, Pre-visit Phase, Visiting Phase and Post-visit Phase. Each state has

multiple sub states. In this sub-section, an attempt to elaborate each sub state is made. It is expected that the process will also provide a system walkthrough for readers.

3.4.1 User Registration

The user registration is a four step process. Figure 3 and Figure 4 depict the registration process. First, a user needs to select a user id and password. The system checks if the user id is available.

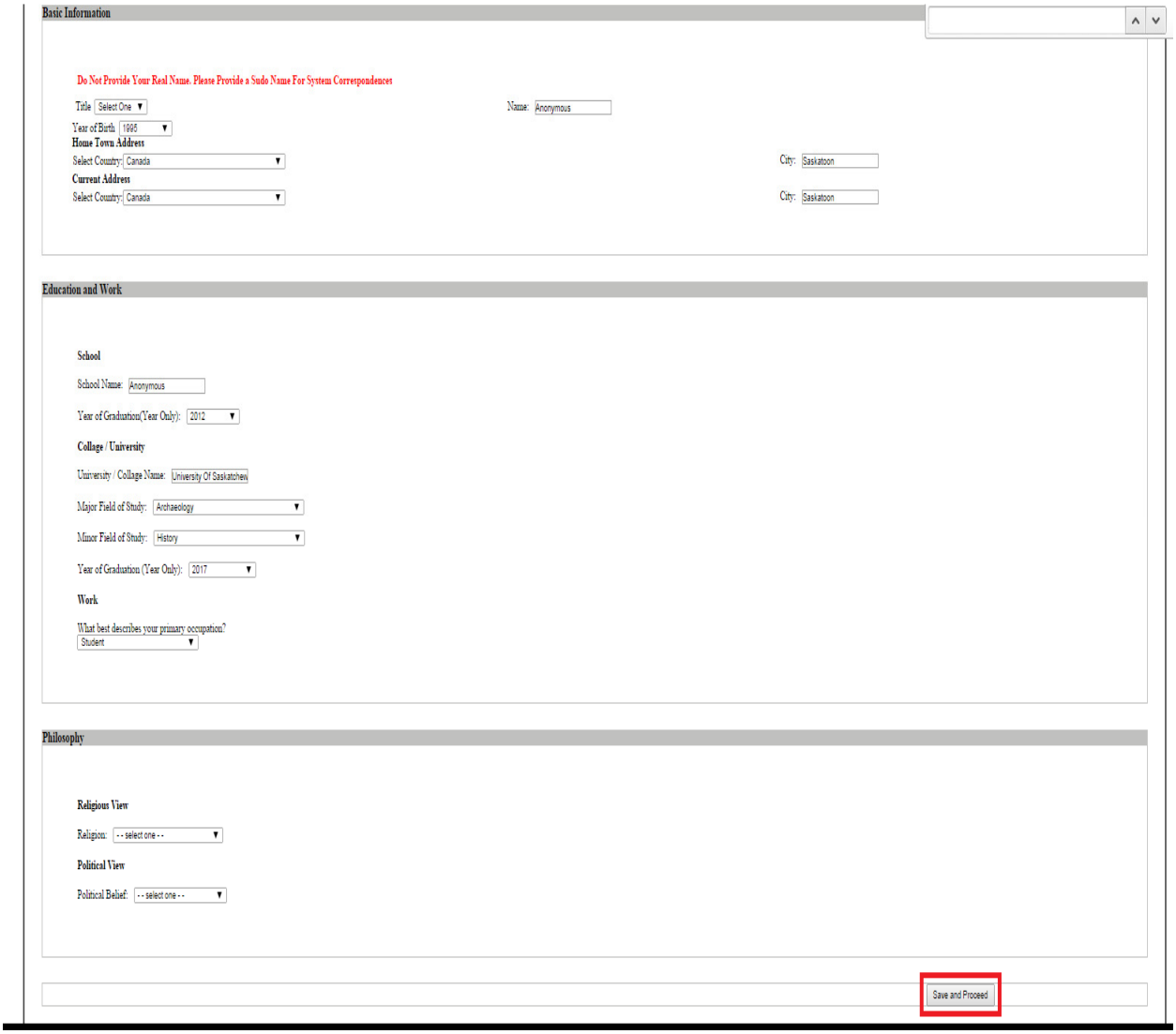

Figure 3: User Registration 1

If the user id is available, it takes the user to the next state where some background information is collected. Background information includes basic information about the user, educational background, occupation, political view and religious belief. All fields in this state are optional. A visitor may choose to fill up or omit any section. Background information collected in this state is vital for creating a user profile.

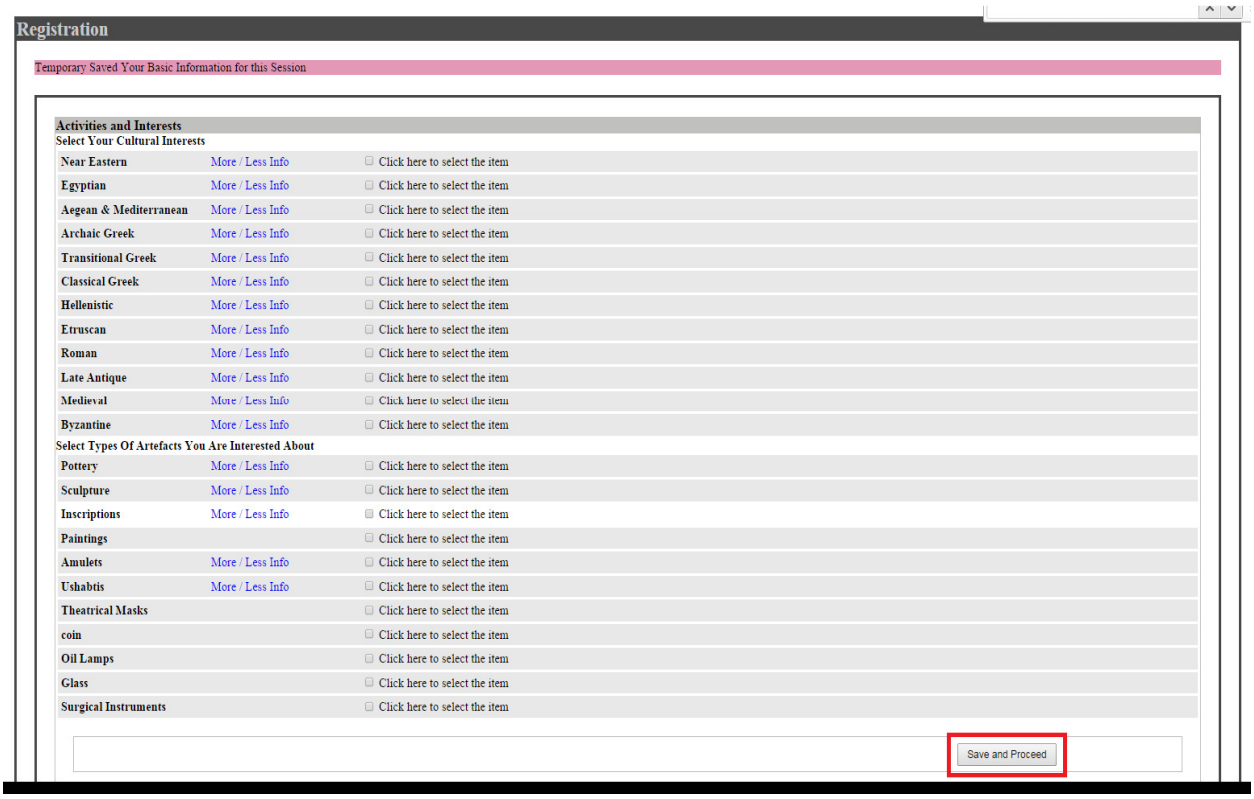

Figure 4: User Registration 2

3.4.2 Recommendation Feature

There are three basic types of recommendations available in the Museum Explorer. They are: Recommendation from Curator, Recommendation based on Personal Interests and Recommendation from Similar People. Besides, there are refinement options available for recommendation features. A visitor can refine recommendation based on artefact types or cultural origin and receive recommendation from available types on given subset. In figure 5, it shows how the recommendation feature is accessible on the top left corner of the screen. On the right panel refinement options are highlighted. Once a user selects a cultural origin / artefact

type, it gives three available recommendation types to select how the list needs to be sorted. For instance, a user selects Egyptian from the cultural origin type. The Egyptian box expands to show three recommendation types (curator/personal interests/similar people). Once a recommendation type is selected; the system sort out artefacts from Egyptian era based on recommendation type request.

Figure 5: Recommendation features

3.4.3 Follow Patrons

The follow Patrons feature is offered during the post-visit phase. It allows a visitor to follow a previous visitor's trail and path. After the follow patrons feature is selected; it gives a list of previous visitors sorted based on similarity on background and interests (figure 6). Once a visitor is selected from the list; the system shows the summary of activities carried out by the visitor (figure 7).

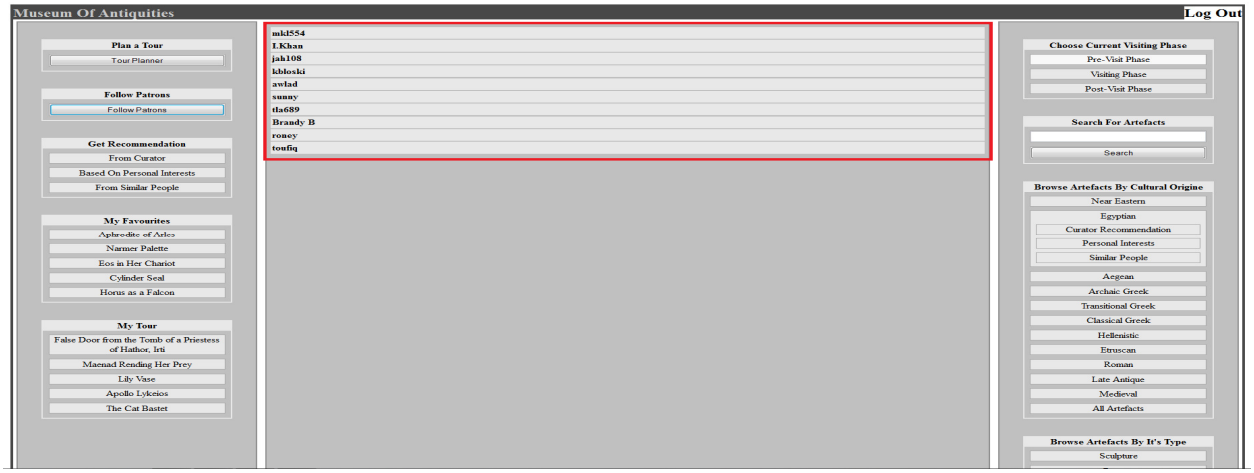

Figure 6: Follow Patrons 1

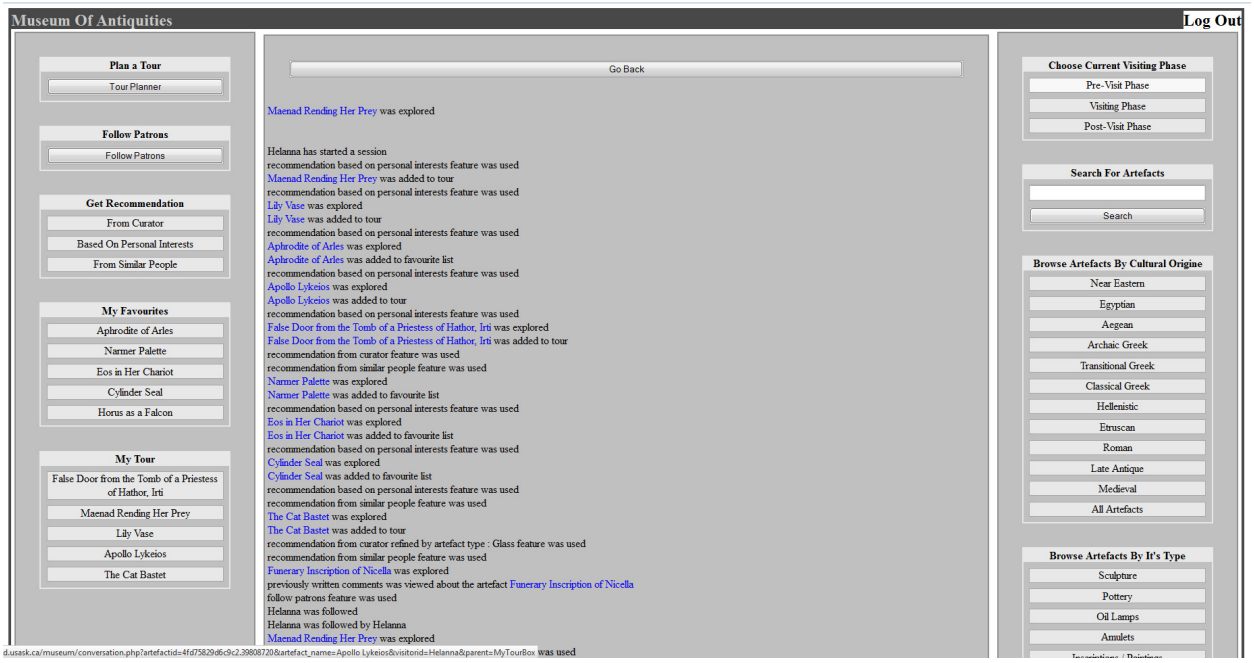

Figure 7: Follow Patrons 2

3.4.4 Tour Planner

Tour Planner is the most useful tool offered during the pre-visit phase. According to the study participants, it is the most useful feature offered by the system. After a visitor chooses to plan his/her tour; a request to specify available time is prompted (figure 8). Once the time is specified,

the system goes to the state where all functionalities to plan a tour is available. On the left panel, there are two boxes. On the top left box, a list of favorite artefacts that is not already added to the tour is shown. On the bottom, list of artefacts added to the tour is shown (see figure 9). Both boxes are editable. From the favorite box, a user can select one or more artefacts and add them to his/her tour by pressing Add to My Tour button inside the box. Once the item is added to the tour, it moves into the My Tour box and disappears from the favorite box. In the My Tour box, a user can delete one or more items from the tour by pressing the delete button. Selected items are deleted by that action. If the item belongs to the favorite list, it goes back to the favorite box. Inside the My Tour box, the system draws a red line if the number of artefacts added to the tour is more than the available time. A user can move an artefact up or down the list by pressing the up or down arrow. Selected item will move up or down. Only one item can be moved at a time. On the right panel, recommendations are available to be added to the tour. Only the artefacts on display are available here. The recommendations are sorted based on three matrices. They are

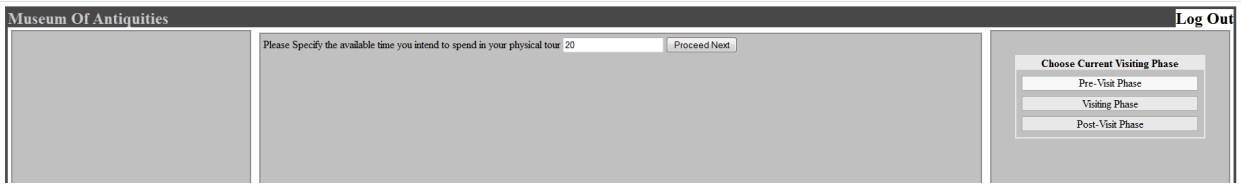

Figure 8: Tour Planner 1

Figure 9: Tour Planner 2

curator's rating for the artefact, visitor's interests and relative popularity of the artefact. First, all artefacts are rated (point based rating) based on above mentioned matrices. Afterwards, the artefact list is sorted in ascending order, where the artefacts with higher point standing stand on top of the list. The curator rating constitutes one third of the total points. The interest matrix combines visitor's interest on cultural origin and artefact types (information collected during the registration process - See figure 4). and it carries one third of total points. Lastly, the popularity matrix combines all types of interactions made with artefacts by previous visitors. Interaction with artefacts involves endorsements, comments and bookmarks. This also carries one third of the total points. The recommendation feature offered here takes a simple but unique approach to produce a recommendation list. The user can select one or more artefacts from a recommendation list to be added to the tour. By clicking on artefacts in the recommendation list, the user receives detailed information about that artefact in the middle panel. Once the tour planning is completed, the "finish tour planning" button needs to be pressed to complete the pre-visit state of the system.

3.4.5 Visiting Phase

During the visiting phase, limited numbers of features are available. On the left panel, My Tour box is available (Figure 10). Using My Tour box, a visitor can follow the tour that was planned during the pre-visit phase by the Tour Planner tool. Clicking on any artefact, detailed information is loaded on the middle panel. When the detailed information about an artefact is loaded at any point; the action box is loaded on the top corner of the left panel. Endorsement (like/dislike),

Figure 10: Visiting Phase

comment, bookmark and query functionalities are available inside that box. On the right panel, Search for Artefacts box is available to have quick access to random artefacts (Figure 3.10). It is expected that a visitor will spend more time with museum exhibits while taking a physical tour. Taking this into consideration, offered functionalities are reduced to minimum to eliminate any confusion that interactivity may introduce.

3.4.6 Post-Visit Phase

Four features are offered during the post-visit phase. On the left panel, Post-Visit Summarizer, My Favorites and My Tour box are available. On the right panel, Search for Artefacts and

Figure 11: Post-Visit Phase

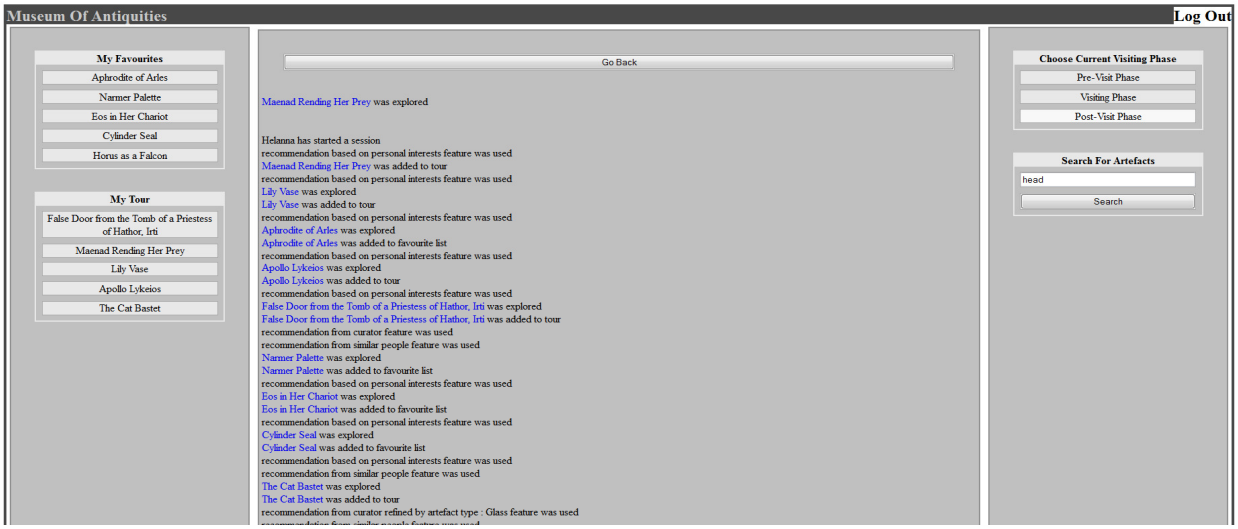

Figure 12: Post-Visit Summarizer

Switch phase box is available (see Figure 11). The middle panel is generally empty. If a user selects an artefact, the middle panel is populated with the detailed information about that artefact. Functionalities in post-visit phase are offered keeping three main principles in vision. They are: allowing a visitor to revisit his/her experience, providing a scope for the visitor to play the expert user's role and giving quick access to favorite artefacts. The Post-Visit Summarizer (figure 12) produces a summary of activities a visitor has carried out until that point. In other words, it allows a visitor to revisit his/her experience. It appears on the middle panel. Summary of activities are presented on plain text. Only artefact names appear highlighted. By clicking on an artefact name; user receives detailed information about that artefact on the middle panel and action box appears on top of the left panel. At the end of a visit, endorsements and comments made by a visitor are considered with higher weight. During post-visit phase, a visitor has access to his/her favorite list, tour and search for artefacts tool. My Favorite and My Tour box appear on the left panel and the Search for Artefacts tool appears on the right panel.

3.4.7 Search For Artefacts

Search for Artefacts is a tool that gives quick access to artefacts. A search query can be made based on artefact names. It can produce results both on full or partial name of an artefact. If an

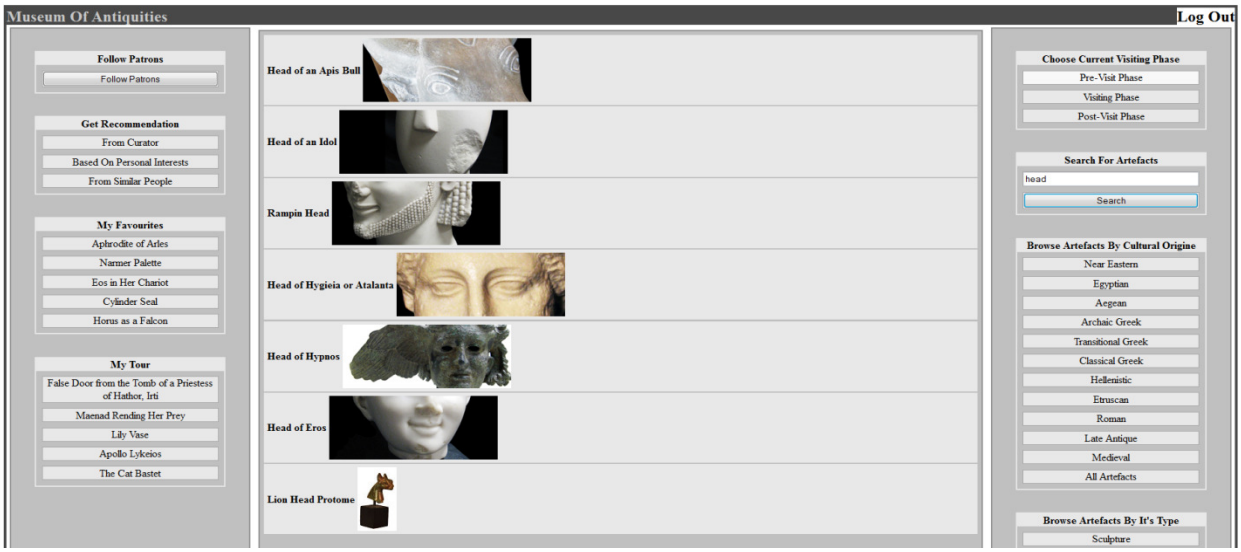

Figure 13: Search for Artefacts

exact match is not found, a list of closest matches are presented (figure 13). Name of the artefact and a thumbnail picture is presented side by side on the list. A user can click anywhere on the highlighted box to get detailed information about that artefact.

3.4.8 Action Box

The Action Box appears when a user chooses to explore an artefact. Once (see Figure 14), detailed information is retrieved; the action box appears on the top corner of the left panel. The box contains seven functionalities. Using these functionalities a user can like or dislike an artefact, write comments about it, view previously written comments, bookmark the artefact and press not interested to go back to previous state.

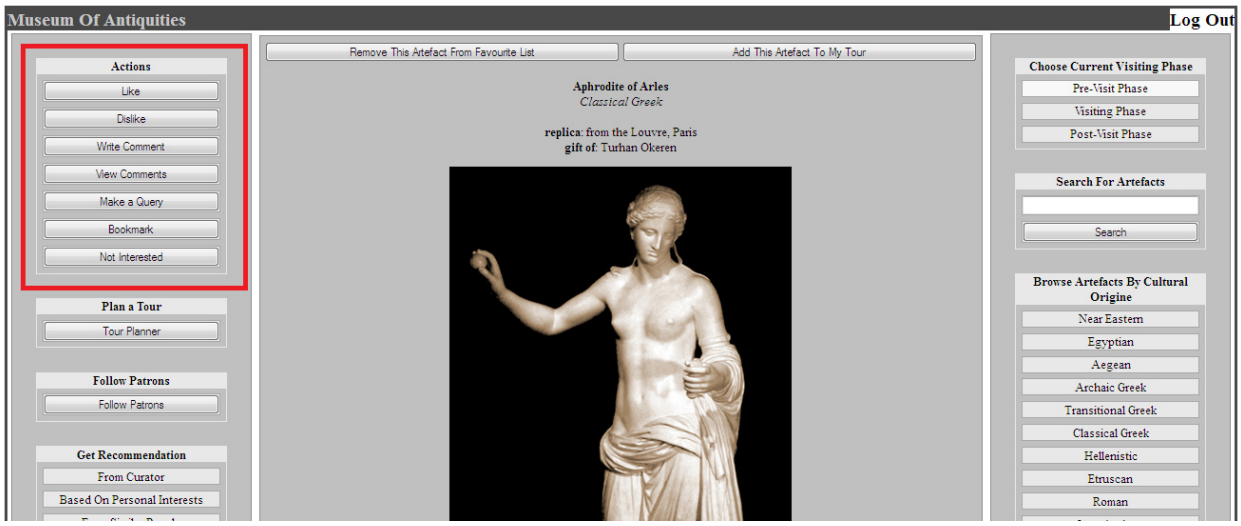

Figure 14: Action Box

Using the above functionalities is fairly simple. By pressing the like or dislike button, a visitor endorses an artefact and receives a message that confirms. Once a user presses the Write Comment button, a comment box appears on top of the middle panel. After writing a comment, a user needs to press the send comment button to save the comment. To view previously written comments, View Comments button needs to be pressed. Previously written comments are loaded on top of the middle panel. Bookmark button inside the action box can be used to add an artefact to the favorite list. Pressing the bookmark button, adds the artefact into the favorite box (if not already added). Lastly, the Not interested button simply take a user to previous state.

3.4.9 Quick Link to Favorites and Tour

Once detailed information about an artefact is loaded on the middle panel; quick links to add the artefact to favorites/tour appears on top of the middle panel (figure 15). Functionalities are offered based on the current state of the user/visitor. For instance, an artefact can be added to the tour only during the pre-visit phase. During the pre-visit phase, if the artefact is already added to the tour; the button will appear with a label “Remove From the Tour”. Otherwise, label of the button would be “Add The Artefact to My Tour”. Similarly, during the post-visit phase, a visitor can not add or remove an artefact from the tour. A visitor can add or remove artefact to favorite list at any phase. Thus, quick link functionalities are offered based on context.

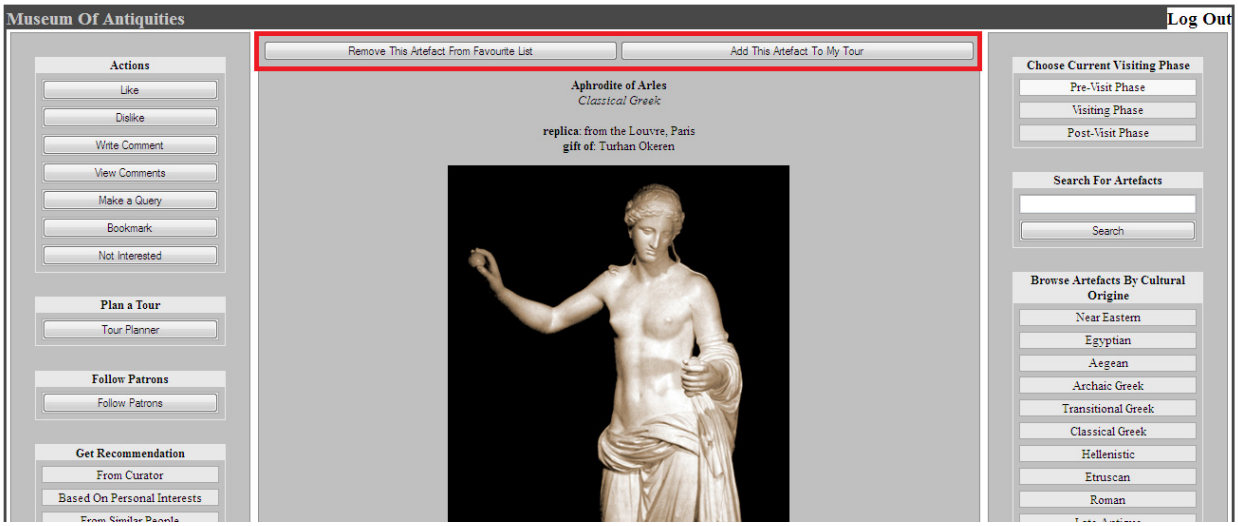

Figure 15: Quick link to favorites and tour

3.5 System Architecture

The implementation work can be divided into three segments. The first segment involved designing the front-end or user interface. The second segment involved building ajax components that could communicate with the server asynchronously and call appropriate php classes. The third segment of implementation involved constructing php classes that would

collect data from the database based on given constraints and return data to the ajax response handler.

While designing the front-end, the main focus was to make the system scalable in all types of device and screen size. The system was tested on various screen sized desktop, laptop, tablet, mobile phones. For a mobile device, we may need different front-end layout to enhance interaction facility. The front-end is designed with a three panel view that can scale from desktop to mobile devices. Due to tiny screen size of mobile devices, users with "fat finger issues" may find it difficult to interact with the system. Therefore, a tablet of 7 inch or bigger would be an ideal sized handheld device. In current design, Information is presented in the middle panel. Right and left panels are used to offer various dynamic functionalities.

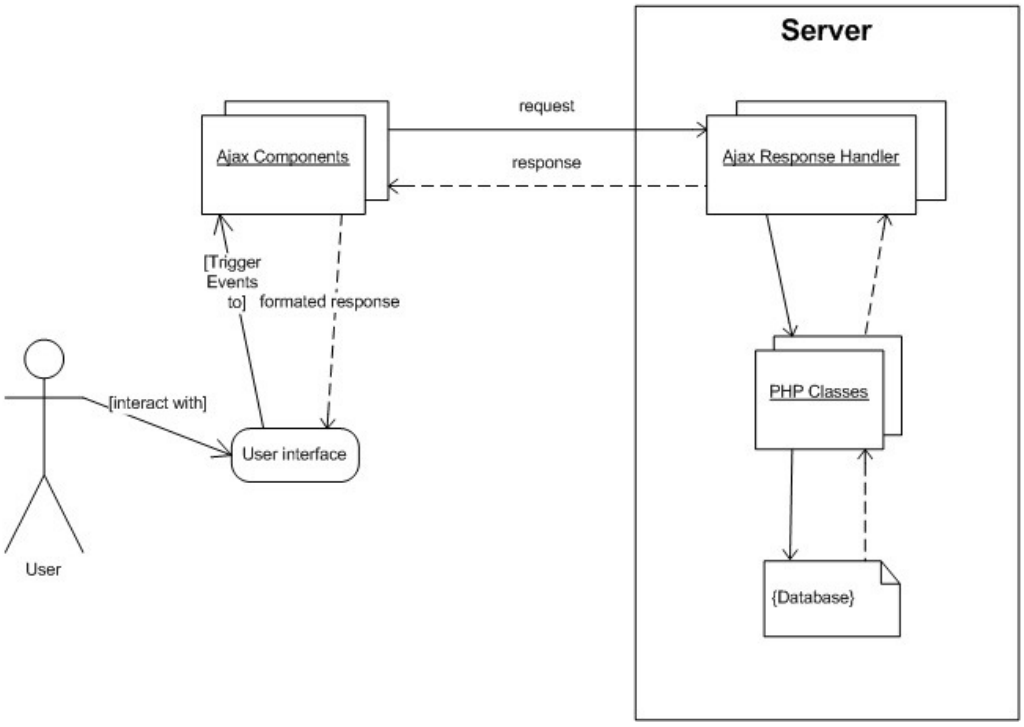

Figure 16: System architecture or component diagram

Analyzing Figure 16, one may understand how different components of the system work together. A visitor interacts with the user interface or front end of the system. A click that activates any functionality of the system sends a request to ajax components on client side. The responsible ajax component sends a signal to the server asynchronously specifying the request. The Ajax request handler on the server side takes account of the request and assigns responsible php class to perform the task. PHP classes standing between the database and ajax request handler components does the reasoning work. If it requires any data from the database; data are acquired through database agent. The Ajax request handler formats any data received from php classes and sends it back to the ajax components on client side. The ajax component on client side reformats the user interface according to a given context and fetches received data into it. Since the entire data acquisition process is performed asynchronously, the system does not need to refresh the user interface. This gives the user an experience similar to using client side software.

In Figure 17, a sequence diagram is presented. This is an elaborative example of how each component of the system communicates with each other and works together to accomplish different tasks. In the sequence diagram, I have shown examples of how three different tasks are performed. In the first task a user requests recommendations from the curator using the user interface. This event triggers a function called get_curator_recommendation() on the client side residing inside ajax component. After collecting required parameters get_curator_recommendation() function makes an asynchronous call to the server. The ajax request handler component in the server determines the type of request and calls reasoning agent class to handle the request. The Reasoning Agent class assigns the task to get_curator_recom() function inside the reasoning agent class. get_curator_recom() function calls the Database agent class to retrieve data from database on given parameters.

The Database agent class calls the designated function to retrieve data and returns data to get_curator_recom() function in the reasoning agent class. Now, get_curator_recom() function runs the algorithm that produces curators recommendation. A sorted data set is returned to the

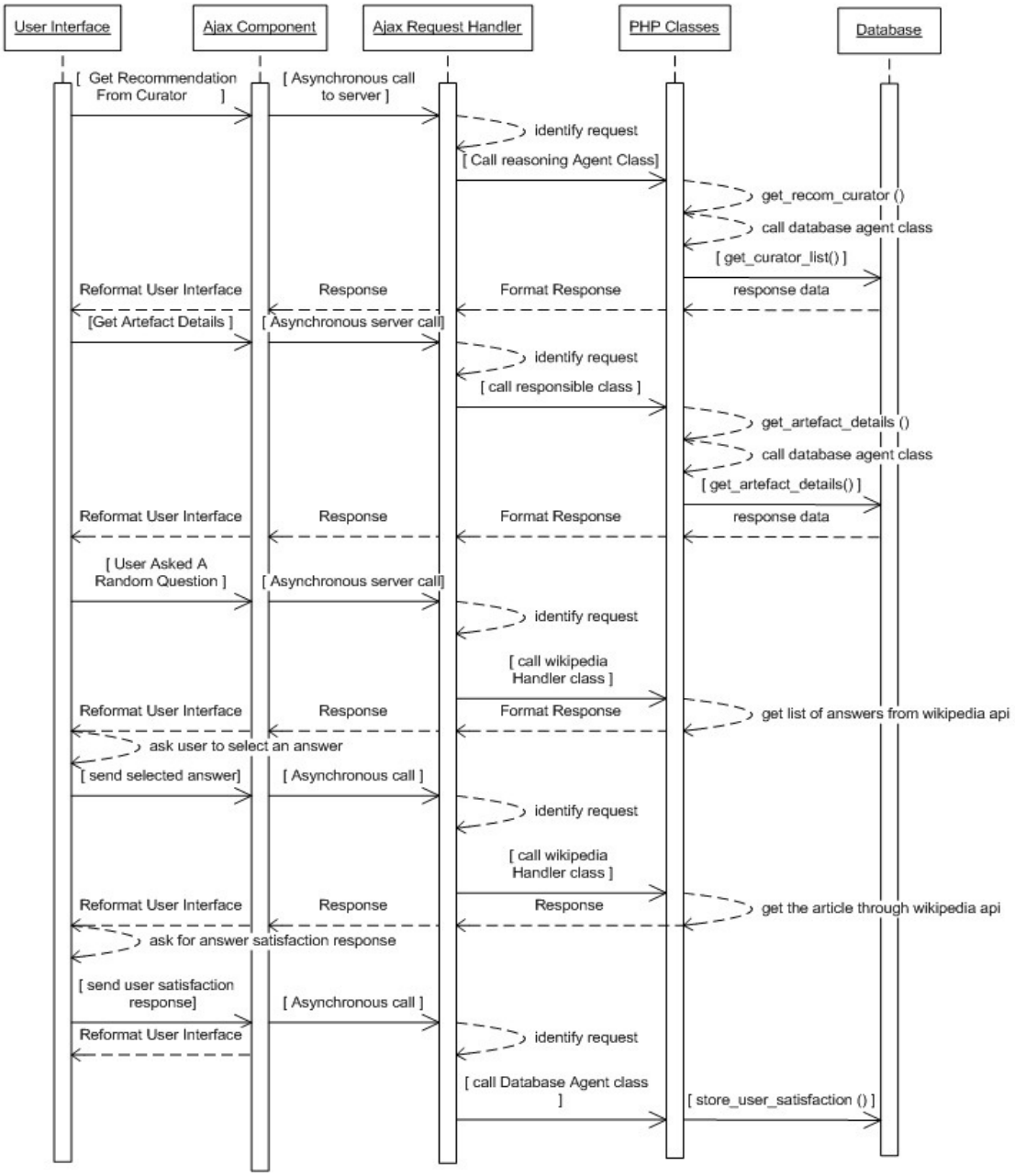

Figure 17: Sequence diagram

ajax request handler component. The ajax request handler component sends the dataset back to ajax components on the client side. get_curator_recommendation() function on the client side receives the dataset. It restructures the user interface according to given context and fetches the newly acquired dataset into it.

The third task of Figure 17, it shows how arbitrary questions are answered by the system. The entire process can be divided into three parts. In the first step, a question asked by the user is transmitted to the server, In return, a list of possible answers is provided through calls to a wikipedia API. In the second step, the user selects a best possible answer and receives the detailed wikiperia article. The last step is an optional user satisfaction question. Each of the three steps above are conducted following a similar architectural design as was presented for task one. They may have used different functionalities; entire task is conducted following the four tier process shown in Figure 17.

3.6 Algorithms for Recommender System:

The recommender system contains three major algorithms. They are constructed to produce the desired result for each recommendation type available on the Museum Explorer. Initially, the elements of the artefact collection are assigned points based on constraints and then sorted based on these point totals. In the sorted list, artefacts that are tied (having point standings) are assigned points from another set of constraints and sorted again. If there are still ties, points for a third set of constraints are applied and the list is sorted again. At each stage, only the portion of the list is sorted where artefacts have tied point standings.

Recommendations from Curator primarily take account of the curator's opinion about artefacts. At the beginning of this project, curator's rating (on a ten point scale) of each artifact residing in the museum was collected. The curator's recommendation is generated in a three step sorting process. First, the artefact collection is sorted based on curator's initial rating. As expected, the curator provided the same rating for multiple artefacts. To sort artefacts having same rating, the second level sorting is conducted. For the second level sorting, popularity of an artefact is taken into consideration. In this case, the popularity refers to the number of interactions made with the artifact by previous users, the number of positive endorsement received from users, and comments made on an artefact. Based on above mentioned parameter, second level sorting is

completed. At this point, there can be artefacts that still are tied. To sort those artefacts, third level sorting is conducted. In the third level sorting, the visitor's interests in the museum domain is taken into consideration. During the registration process, the visitor's interest in the museum domain are collected (See figure 4). Each artefact falls into one or more category shown in figure 4. Artefacts that matches with the visitor's interest receives more points. Based on this, the third level sorting is carried out. After above mentioned three level sorting, the artefact list generated is the curator's recommendation.

Recommendations based on personal interests are generated by primarily taking the user interests into consideration. Here also three level sorting is performed. In this recommendation type, first level sorting is conducted based on user interests in museum domain. After the first level sorting, artefacts with tied point standing are sorted again based on popularity. To measure popularity of an artefact, interactions, endorsements and comments are taken into consideration. The third level sorting is done on artefacts with tied point standing after the second level sorting. At this point, artefacts are sorted based on the curator's rating. At the end of the three level sorting, recommendations based on personal interests are generated.

Recommendations from similar people are generated as follow: Initially, a list of previous visitors with maximum similarity to the current visitor is generated. This similarity measure considers visitor background and interests (collected during the registration process). Each item of information carries a weight on a 5-point scale and is matched with the current visitor's information. \ After matching, visitors with the highest similarity in average point standing (maximum 5) are selected and their activities are monitored. Monitoring involves comments, endorsement and exploration of artefact. Based on this, the first level of artifact sorting is conducted. After the first level sorting, artefacts with similar point standing are sorted again based on the popularity of each artefact. The third level sorting on artefacts with similar point standing is carried out based on curator's rating. Finally, the sorted list is the recommendations from similar people.

In addition to the above mentioned recommendation types, Museum Explorer offers refinement options. A user can refine the recommendation based on cultural origins and artefact types. Once the refinement type is selected, user proceeds by selecting one of three available recommendation types. So, the sorting is carried on a subset of the museum artefact collection.

Prior to conducting the user study, The Museum Explorer was only informally tested for usability. Feedback was collected from external sources throughout the development process and necessary changes were made based on feedbacks. For instance, the idea of dividing functionalities into three groups and offering them based on context was adopted from feedbacks received from external sources. Usability testing was conducted during the user study. Study participants were asked to rate the system considering the overall user experience at the completion of each phase. Comments received from the user study were mostly about various functionalities and their usefulness and interestingly, there was no comments written about the usability of the system. In multiple instances, study participants mentioned that the Museum Explorer has a simple and easy to use interface.

The museum explorer was built following an incremental approach. Direction of this project has changed somewhat throughout the project's duration. Therefore, changes in design and implementation took place during the course of the project. Due to its modular architecture, it allowed us to include features and functionalities with a very little additional cost. For instance, the museum explorer was initially a recommender system that offered three types of recommendations. Refinement options based on artefact types and cultural origin were added after recommendation features. Afterwards, options to interact with artefacts through various functionalities (endorsement, comment, and bookmark) were added under the Actions Box. While adding a feature, it involves writing functions for each tier (See four tier architecture in Figure 1). A new function may call previous functions. But, they mostly work independently. The architecture of the system allows us to include features and functionalities without rewriting any segment. The use of Ajax framework allowed us to render portion of the user interface asynchronously without any interruption and provided a consistent user experience. It is

important to reinstate the statement that the system was designed with a vision to address the research questions raised in this thesis work. The primary research question was to determine if we can enhance visitor's experience in a museum by providing intelligent and interactive communication features. To accomplish the goal, visitor's experience was divided into three phases and tools were built for each phase. The system has features that help a visitor to transfer their experience from one phase to another. Thus, on technical level it has an architecture that allows us to further develop it following iterative model. Addressing research goals, tools were designed and built with a vision to satisfy research goals. For further technical details, detailed code can be provided upon request.

Chapter 4

System Evaluation

4.1 Study Design

We executed both subjective and objective evaluation process to measure performance of the system (Museum Explorer). The evaluation study was carried out at the Museum of Antiquities located at the University of Saskatchewan. Study participants were requested to fill up a user satisfaction survey. The survey questionnaires were designed to acquire objective feedback from users (study participants). Behavior of participants (usage data) was also taken into consideration to carry out the subjective evaluation. To answer research questions raised in this thesis work, a combined approach is taken in this section. Objective answers were substantiated with the help of behavioral analysis of the study participants.

The Museum Explorer database was initiated using the Museum of Antiquities. After receiving consent from the curator, required information (pictures of artefacts, descriptions and metadata) were parsed from the existing museum website. A separate interface was built for the curator for giving us feedback. Given feedback was used in the curator recommendation. To solve the cold-start problem in the recommender system, I inserted some dummy data into the system considering several ideal visit scenarios. Since, the system relies heavily on empirical data; dummy data is required to initialize each module effectively. While performing data and user behavior analysis, existing dummy data was excluded to get actual results.

The study is to evaluate Museum Explorer divided into three segments: pre-visit, visit and post-visit. A study participant (volunteer visitor) is required to carry out a defined set of tasks in each segment. At the end of each segment, the study participant is requested to complete a short questionnaire. A total of 15 questions were asked during the study. At the beginning, a task list is given to participants. The task list comprises a defined set of tasks the participant is expected to complete in each phase. A participant may further assist the study by providing more usage data independently. The task list assured a minimum level of participation by a participant.

During pre-visit segment each participant was guided towards the existing museum website to gain a basic understanding about the static website that currently exists for the Museum of Antiquities. After a few minutes (less than five) the participant was guided to register with the Museum Explorer. After the registration, participants were encouraged to explore the "Museum Explorer". The exploration phase consists of three major tasks. They are: 1) explore at least five artefacts (endorse them positively/negatively and comment on those artefacts). 2) Use the recommendation feature and explore the follow patrons feature. 3) Plan a visit using "Tour Planner" tool. Each task comprises a set of subtasks. It is important that the user follows the order defined in the task list. This ensures that there is enough usage data for the system. The usage data ensures that each component of the system is examined and that it performs as desired. At the end of the pre-visit phase, two objective questions related to user experience is prompted.

In the second segment (visiting phase), the participant was guided toward the Museum of Antiquities to take the physical tour. Since, the visitor is expected to spend time on museum exhibits; the level of interaction with the system in this phase is expected to be limited. The My Tour and Search for Artefacts features are the only ones available in this phase. So, a visitor receives limited degree of support as they follow through the planned tour or explore other discovered artefact using the search functionality. Since, the system does not offer navigation support; a human guide helps the participant to follow their planned path for the tour. If the visitor is inclined to explore another artefact not on the tour, the Search for Artefact feature is

available to obtain more information. At the end of this segment, two more questions are presented to the participant.

In the last segment, participants were requested to complete three more tasks. Assigned tasks include using the post-visit summarizer tool, revisiting any bookmarked artefacts and replying to any comment fellow patrons have directed towards the participant. Post visit summarizer tool allows a visitor to revisit his/her experience so far. By replying to comments, a participant can play the role of an expert user. In this process, knowledge and experience of an expert user are shared to build a community based on mutual interests. In the end of the third segment, twelve more questions are asked. In a typical scenario, the duration of the session including pre-visit, visiting and post-visit segments was 25 to 30 minutes.

In this study, I recruited 10 participants. Participants were guided through the entire course of the study. Seven out of ten participants were part of volunteer group associated with the "Museum of Antiquities". Some diversity among participants was desirable in the context of this study. Therefore, three participants were included with no prior understanding this domain. The volunteer group played the role of expert users and provided critical feedback. The remaining three participants were general users having very little expectation about the system or understanding about the domain.

Questions asked of participants during the study were close-ended, objective and quantifiable. There was scope for writing brief open ended statements for some questions. Those statements were not formally evaluated. They are considered as suggestions from users. Objective questionnaire items presented during the study are of two types. In the first type, a participant could select an answer from a set of options. In the second type, a participant was requested to rate an aspect of the system on a scale of 1 to 10. To evaluate each research question, specific questionnaire items associated with the visit phases were examined various phases. In most cases, keystroke level behavior of participants is also considered to derive the final answer.

Descriptive statistics summarizing user opinions and reactions on the survey are presented in the following subsections. Summaries of actual user keystroke behavior with the Museum Explorer tool are also presented. An effort is made to compare the survey data with the usage data to confirm the observations from both sources.

4.2 Connecting Three Major Phases

The idea of building an integrated solution in this domain arose a vision to connect user experience across various phases of a museum visit. Museum Explorer has features that support a user to connect and transfer user experience across three major phases. Analyzing table 2, it appears that there was 100% agreement among participants about the general usefulness of the Tour Planner. All participants claimed that the Tour Planner is a useful addition to the system. A visitor commented that The Tour Planner will help those unfamiliar with what the museum has on display. Another participant stated that she found the tool very effective, easily understandable and innovative. The average rating for the usefulness of the Tour Planner tool was 8.6 out of 10 with a very little disagreement (standard deviation of 1.35). The tour planner was largely considered to be useful addition to the system. Since, the primary purpose of this tool was to connect and transfer visitor experience; it can be assumed that the tool effectively connected pre-visit and visiting phase and allowed a visitor to transfer his/her experience.

		Tour Planner
Do you think the Tour Planner is a useful addition?	Average Rating	Standard Deviation
100% (yes)	8.6 (out of 10)	1.35

Table 2: Tour Planner Feature Analysis

The concept of a Follow Patrons Feature was also endorsed positively by participants. 90% of participants liked the notion of following other people's trail (see table 3). It has received a mixed rating from participants. The rating of 8 (out of 10) shows the usefulness of the feature. But, the standard deviation of 1.84 indicates some disagreement among participants about the level of usefulness (see table 2). An observation among study participants may explain the cause for this disagreement. 70% of the participants came from a volunteer group affiliated with the Museum Of Antiquities. The rest were not familiar with the museum or with each other. Participants from the volunteer group appeared to be curious about each other's interests. Therefore, Agreement among the volunteer group is not surprising. On the other hand, participants not highly motivated or interested about this domain found this feature less useful. So, the diversity among participants may have caused the disagreement in rating this feature. The primary purpose of this feature was to facilitate users to share their experience. In other words, it allows a visitor to follow experiences of previous visitors in different phases and connect their experience with the current visitor's experience. The results validate the assumption about usefulness of this feature.

		Follow Patrons
Is the notion of following other people's trails (follow patrons feature) a good idea?	Average Rating	Standard Deviation
90% (yes)	8 (out of 10)	1.84

Table 3: Follow Patron Feature Analysis

Post-visit Summarizer is another feature added to connect user experience across three major phases. The feature was designed to connect user experience of pre-visit and visiting phase with the post-visit phase. It received lowest rating of 6.8 (out of 10) from participants with a standard deviation of 1.66 (see table 4). The rather low standard deviation of 1.66 implies that there was

agreement among users about the marginal utility of this feature. Reasons for receiving poor rating from the participants may involve several factors. The feature shows all interactions made by the visitor with the system. So, it is basically an interaction chart where no refinement or summarization is performed. Summarization of user activities could make the feature more intriguing. Due to the scope of this project, further improvement of this feature was left for future work.

		Post-visit Summarizer
Does user involvement in community activities on post-visit phase further enhance user experience?	Average Rating	Standard Deviation
60% (yes)	6.8 (out of 10)	1.66

Table 4: Post-Visit Summarizer feature analysis

In this study, artefacts were explored 300 times by the 10nparticipants using the system. Of these, 40% (or 121 times) the exploration was conducted using tools that were built to connect user experience across three major phases. Artefacts explored using above features are endorsed positively 92% of the time (112 out of 121). The Tour Planner was considered to be the most useful tool. Further enhancement in Follow Patrons and Post-visit Summarizer feature may improve utility of those features. Since Follow Patrons and Post-Visit Summarizer feature heavily depends on usage data; larger involvement of users may also help to improve utility of these features.

4.3 Recommendation Approaches

Recommendation feature is generally a useful tool in any system that offers access to numerous entities. The primary objective of a museum tour guide system is to direct visitors/users towards

their objects of interest. Recommendation features in Museum Explorer are designed with this objective in mind. There are three types of recommendation offered in Museum Explorer. They are: Curator Recommendation, Recommendation based on Personal Interests and Recommendation from Similar People. Each type uses a different set of constraints to generate the recommendation list. A research question raised in this thesis work was to make a comparison/usability study of above recommendation types. Result shows that the recommendation features as a whole has received a decent user rating of 7.6(average). Standard deviation of 2 suggests that the feature was rated extremely high by some participants. Contrariwise, others rated it poorly. Interestingly, analyzing the usage data; it was found that 41% of total exploration of artefacts was carried out using recommendation features. 38% of artefacts were endorsed positively after exploring them using recommendation features. So, the recommendation features were the main source for exploring new artefacts. 38% positive endorsement rate suggests that it has provided an acceptable support for accessing museum exhibits.

Curator recommendation has received the highest rating of 8 in available recommendation types. Standard deviation of 2.56 suggests that it received a mixed rating from participants (see table 5). The usage data depicts the actual usefulness of this recommendation type. 43% of total exploration was conducted using curator recommendations. So, it was the most frequently used recommendation type. Moreover, half of the artefacts were endorsed positively (51%) after exploring then using this recommendation type (see table 6). This is also the highest endorsement rate comparing with other types. The curator's recommendation can be viewed as expert opinion in this domain. It appears that the participants heavily relied on expert opinion in exploring artefacts (considering 43% exploration carried out through Curator Recommendation). Results also shows that expert's opinion were mostly endorsed by visitors in a museum (51% positive endorsement) (see table 6).

Recommendation Features		
	Average	Standard Deviation
Overall Rating For Recommendation Features	7.6	2
Rating for Curator Recommendations	8	2.56
Rating For Recommendations based on Personal Interests	7.6	1.49
Rating For Recommendations From Similar People	7.6	1.24
Rating For Browse By Cultural Origin	7.8	1.16
Rating For Browse By Artefact Types	8.2	0.74

Table 5: Rating for Recommendation Features

Recommendation Types				
	Explored	**Percentage**	**Positive Endorsement**	**Percentage**
Total Using Recommendation Features	123	41%	47	38%
Curator Recommendation	54	43%	28	51%
Recommendation Based on Personal Interests	47	38%	12	25%
Recommendation From Similar People	22	17%	7	31%

Table 6: usage analysis for recommendation types

Refinement Options For Recommendation Types				
	Explored	Percentage	Positive Endorsement	Percentage
Browse By Cultural Origin	67	87%	25	37%
Browse By Artefact Types	10	13%	4	40%

Table 7: usage analysis for refinement types in recommendation features

Recommendation based on personal interests has received a rating of 7.6 with a little disagreement among participants (standard deviation of 1.49, see table 5). Analyzing usage data, it appears that the recommendation type could not perform up to the expectation level of participants. 38% artefacts were explored using recommendations based on personal interests (see table 5). It clearly suggests that the participants were moved by the idea of receiving recommendation based on their personal interests. Consequently, the endorsement rate of 25% also suggests that recommendations made using this feature was not considered useful by participants (see table 6). In this recommendation type, artefacts were sorted based on user interests, popularity and expert opinion. Since, there were very little usage data available; this specific type of recommender system could not perform up to optimal level. Therefore, the recommendation type may have been considered to be less useful.

Recommendation from similar people feature has received a decent rating of 7.8 (See table 5). Participants were agreeable about the usefulness of this recommendation type. Analyzing the usage data, a different opinion prevails. Only 17% of total artefacts were explored using this recommendation type (see table 6). It indicates that the participants have found the idea of receiving recommendation from similar people less intriguing. The endorsement rate of 31% shows that the recommendation type was not highly useful (see table 6). Again, the amount of

available usage data may have played a significant role in making the recommendation type less useful.

There were methods of refining the recommendation list by cultural origin of artefacts or by artefact types. Browse By Cultural Origin method received a rating of 7.8 (see table 5). On the other hand, Browse By Artefact Types has received a higher rating (average 8.2) from study participants. There was very little disagreement among participants about the usefulness of above features (see standard deviation in Table 5). According to the survey questionnaire feedback, there was a very little difference in the usefulness of above discussed features. But, analyzing usage data; it gives us a different prospect about user's perception in this domain. 87% of total artefact exploration carried out using refinement options in recommendation features were conducted by Cultural Origin filter. Only 13% were carried out by Artefact Type filter (see table 6). This implies that the users in this domain perceive the idea of receiving recommendation using cultural origin filter more appealing.

Observations related to recommendation features can be concluded in three points. First, curator recommendation was perceived to be the most useful recommendation type. Consequently, expert (curator) opinion played the most influential role in shaping user preferences. Secondly, greater volume of usage data is needed for other recommendation types to perform in optimal level. Lastly, the refinement of recommendation by cultural origin is perceived to be the most useful refinement feature.

4.4 Visitor's Impression Towards Post-Visit Experience:

Post-visit experience of a visitor is mostly overlooked in other systems. Very little work has been done so far targeting this phase of user experience. In this thesis work, a significant amount of effort was put together to improve user experience during this phase. The four post-visit tools were: Post-visit Summarizer, My Tour, My Favorite and Search for Artefacts. Besides, users can endorse, comment, bookmark artefacts and ask random question.

Only 16% of the total interactions with the system were made during the post-visit phase (see table 8). This suggests that visitor's interest towards a museum may drop off during the post visit

Total number of interactions made with the system	931	
Total number of interactions made during post-visit phase	151	16%
Total number of artefacts explored during post visit phase	71	23%
Endorsement made during post visit phase	2%	
Comments made during post visit phase	39%	

Table 8: User activities during post-visit phase

phase. Since, the visitor has already explored the collection of the museum; it is understandable that they may have less interest during this phase. The idea of introducing Post-Visit Summarizer was driven by the belief that a visitor would like to reflect on his/her museum visit experience during this phase. It received an average rating of 6.8 out of 10. Comments were made expressing doubts about the usefulness and relevance of this feature. Possible reasons for receiving negative feedbacks were discussed in previous section. It is still unclear where to begin on improvements of this feature. 23% artefacts were explored during post-visit phase. Out of 23% of only 2% were endorsed positively. Interestingly, 39% of comments were written during this phase. It clearly suggests that visitors were comfortable writing about their experience at the end of their visit. Visitors may prefer revisiting artefacts they visited before and provided expert opinion on them. Since, the recommendation features are absent during this phase; a very little scope is available to explore new artefacts. My Favorite and My Tour feature gives access to previously visited artefacts. Only Search for Artefacts feature gives access to new artefacts given the fact that a visitor can recall some part of the name of the artefact he/she is looking for. So, the 23% exploration rate of artefacts suggests that some visitors are interested to revisit

artefacts/experience during this phase. The post visit summarizer tool was built to address that information need. Unfortunately, more work needs to be done to produce better summary of activities. It is not clear why the post-visit summarizer tool received such poor rating. It seems that idea of building this tool was correct. Due to the scope of this project, the simplified implementation of this tool might have compromised its utility.

Conclusions that can be drawn based on above results and analyses include: Visitor's interest towards a museum is restricted primarily to the visited artefacts during post-visit phase. In other words, a visitor is inclined towards revisiting most memorable during the post-visit phase.

4.5 Visitors' Impressions Towards Interactive Features

Museum Explorer is a highly interactive system. Various tools were added targeting its optimum application in answering proposed research questions. Comparing with the existing static Museum of Antiquities website; Museum Explorer's extended level of interactivity may introduce confusion. It is important to determine if the users are comfortable using an interactive interface in this domain. To better manage the interface, three set of functionalities were offered in three major phases. Features were chosen considering the information need of a user on given context. Initially, participants were invited to use the static museum website. It allowed the visitor to compare Museum explorer's dynamic and interactive features. In the end, participants answered questions related to interactive features and rated various functionalities of Museum Explorer.

The Table 9 suggests that the interactive features offered by Museum Explorer were highly rated. All features were rated above 7 except post-visit summarizer. Highest standard deviation of 2 suggests there were arguments about the usefulness of various features. It also suggests that the rating didn't change dramatically from one participant to another. Standard deviation was below 1.5 in six out of nine features that were rated. When comparing with the existing static Museum of Antiquities website, 90 of percent participants found Museum Explorer a better source of

information. One participant said “The interactive features are essentially the contributing success of the Museum Explorer; the features are flexible and very simple to use and access”. While comparing the Museum Explorer with existing static museum website, a participant wrote

Name	Average	Standard Deviation
Recommendation features	7.6	2.0
Tour Planner	8.6	1.35
Follow Patrons	8	1.84
Post-visit Summarizer	6.8	1.66
My Tour	8.3	1.41
My Favorites	8.6	1.28
Search for Artefacts	8.7	1.48
Browse By Cultural Origin	7.8	1.16
Browse By Artefact Types	8.2	0.74

Table 9: Visitor’s impression towards interactive tools

Compared with the static museum website, is the Museum Explorer more useful?	Compared with the static museum website, did you find the Museum Explorer's interactive features more useful?
90% yes	90% yes

Table 10: Comparison of Museum Explorer with the existing site

that “It is less prosaic and more interactive, engaging individuals who are looking to visit the Museum of Antiquities and illuminating the uniqueness of the experience. The Museum Explorer is factual and informative without being "static" there is mobility and personality to it”.

Based on results and analysis above, it can be concluded that the interactivity of Museum Explorer is considered to be useful. The interactive features were highly rated as a whole and as separate entities. So, the participants reacted positively towards interactive features.

4.6 Contribution Towards Overall User Experience Enhancement

The primary purpose of this thesis work was to enhance the experience of a museum visitor. User experience of a museum tour was divided into three phases. A number of tools were built to address information need of a visitor in each phase. Methods adopted to enhance visitor’s experience were to offer better recommendation feature, connect visitor experience across three phases and provide intelligent and interactive communication tools. The contribution shall be evaluated taking above goals into consideration. Besides, survey questionnaire and usage data should also be used to evaluate the contribution.

System rated after Pre-Visit Phase		System rated after Visiting Phase		System rated after Post-Visit Phase	
Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation
7.8	0.97	8.4	0.66	8.5	1.11

Table 11: user ratings for the Museum Explorer in three major phases

Table above demonstrate that the Museum Explorer was highly rated in each phase. In another observation, ratings for the system were slightly increased when the system was used for longer

period of time. After using the static museum site; a user presented with the museum explorer can be puzzled with the extended set of interactive features. A fair amount of learning is required to better utilize the system. The initial learning process may have caused the rating of the system to be a bit lower. Standard deviation was low indicating close agreement among participants about usefulness of the system. Once the users became familiar with the system and were able to transfer their experience to the next phase; usability of the system was rated higher.

80% of participants felt that the Museum Explorer successfully connected the three major phases. A participant wrote that "Because they were all aligned with each other and with the user's needs, they were equally successful in connecting to the universality of the system". Tools that were built to connect user experience across various phases were highly rated (except the post-visit summarizer). Statistics derived from the usage data also suggests that the participants found those tools to be useful (see section 4.2 for usage data analysis. Not presented in a table). It can be concluded based on discussions above that the Museum Explorer was moderately successful in providing options to connect and transfer user experience across three major phases.

In a museum setting, the primary challenge for a curator and a visitor alike is to select artefacts for a visit. Recommendation features help a user to determine the best possible options based on given constraints. In Museum Explorer, three types of recommendation were offered. In section 4.3, a comparative study was carried out among three available types of recommendation. In the questionnaire survey, users highly rated all recommendation features (see table 5). The usage data suggests that the participants had preference among recommendation features and refinement options. When the participants were requested to rate recommendation features, they were rated almost equally high. This suggests that the recommendation features were able to deliver regardless of individual preferences.

Interactive tools/features were highly rated by participants (see table 9). 90% of the participants agreed that the Museum Explorer was a significant improvement over the existing static website. They also agreed that the interactive tools were useful during their visit.

The discussion above illustrates that the participants found the Museum Explorer a generally useful tool that assisted them throughout their museum visit experience. Recommendation features provided a guide to find objects of interest. Interactive tools enriched their experience. The Museum Explorer was perceived to be a useful tool that supports a museum visitor.

Chapter 5

Conclusion and Future Directions

5.1 Conclusion

A Museum tour guide system augmented with computing technology can be weighed down by a high level of expectation. Due to various types of limitations, implementing all ideas in one project becomes unmanageable. The project was implemented in a fairly small sized museum located at the University of Saskatchewan. This thesis work went through an evolution process. The research goal was redefined, research scope was minimized, research questions were reorganized and implementation works were restructured. Results received from the user satisfaction survey and usage data gathered during the study indicates that the project was mostly successful in reaching its goal.

The Museum Explorer was designed to assist visitors throughout the course of a museum visit. The primary goal of this thesis work was to enhance visitor experience in a museum with the help of various intelligent and interactive tools. To better address the information need of a visitor; their experience was divided into three phases. A set of tools were built for each phase. Features were offered that connects a visitor's experience across three phases. Tools such as: Tour Planner, Post-visit Summarizer, Follow Patrons directly contribute towards allowing a visitor to connect and transfer their experience from one phase to others. In addition, there are functionalities that reflect their activities. For instance, bookmarking an artefact includes the artefact into the favorite list. The favorite artefacts list is accessible in all phases. Recommendation features were another contribution made in this thesis work. In a typical recommender system, a user receives recommendation based on predictions made by the system.

Predictions are translated into constraints to derive the recommendation set. In Museum Explorer, users have the option to choose a set of constraints that governs the generation of recommendations. Results demonstrate that the additional freedom to tailor the recommender was appreciated. Intelligence of the Museum Explorer and its interactive nature played a role in the success of this project. For instance, immediate acknowledgements in response to any user activities, dynamic adaptation of the user interface are interactive features of the system. Since the system records keystroke level interaction; a reflection of recorded data through various features offered by the Museum Explorer offers a detailed dataset for further analysis.

An objective evaluation was performed through a user satisfaction survey. To substantiate the result from objective evaluation, a further evaluation was also carried out by analyzing the usage data acquired from keystroke level interaction. It appears that the Museum Explorer was moderately successful in connecting user experience across three major phases. The Tour Planner was regarded as the most useful tool that helps to connect user experience. Various recommendation types were almost equally rated. But, usage data suggests that users in this domain prefer receiving recommendation from a curator. Among refinement options, participants had preference towards the cultural origin of the artefacts. Ninety percent of the subjects agreed on the fact that the interactive nature of the system is useful. So, the idea to offer features and functionalities based on context has proven useful. The interactive tools received a moderately strong rating from study participants. The Post-visit summarizer was the main feature offered by the Museum Explorer during the post-visit phase. The feature was not rated highly by users (study participants). Further refinement of this feature is left for future researchers in this domain.

5.2 Contributions

Contributions made by this project can be evaluated from various dimensions. The initial goal of this project was to enhance visitor's experience in a museum using computer aided technologies. Approaching this goal, several methods were adopted. A system called Museum Explorer was

built that offers an integrated solution for museum visitors. Following were methods adopted to enhance visitor experience in a museum:

- Offering an integrated solution for museum visitors.
- Connecting visitor's experience across three major phases by building tools and offering features that allows a visitor to transfer his/her experience from one phase to another.
- Offering interactive features to enhance user experience while using the Museum Explorer.
- Allowing users to set constraints for the recommender system. To do this multiple types of recommendations and refinement options were integrated in the Museum Explorer.

When the Museum Explorer was designed, above-mentioned methodologies were taken into consideration. After implementing the system, several additional research questions were raised. In consequence, we decided to record keystroke level interaction with the system. Once the usage data became available, various predictions about behavior of users in this domain could be made. So, analyzing contributions made by this project; the discussion needs to be illustrated addressing three major directions. First, contributions made by the Museum Explorer as software. Second, contributions made by answering research questions. Lastly, contributions made by analyzing usage data gathered from the study to better predict behavior pattern of users in this domain.

The Museum Explorer was highly rated as an integrated solution offered for museum visitors (by study participants). Tools developed and features offered by Museum Explorer were also rated highly. Based on results and usage data received during the study, it can be concluded that the software developed for this project made a contribution in this field. Results refined from the study may be considered as contributions made by this project on given domain:

- The Museum Explorer is the first solution that addresses information need of a visitor in all major phases of a visiting experience.

- Methodology adopted to build the Museum Explorer can be used to build solutions in museum domain. The same methodology can be used to build solutions in the informal learning environment (since museum is considered to be an informal learning setting).
- It has tools that allow a visitor to connect and transfer user experience from one phase to another.

Above mentioned contributions are obtained from the subjective and objective evaluation carried out during the study. Analyzing usage data (Objective evaluation) there are some behavior pattern observed during the study that can be utilized developing tools in museum domain or in the informal learning environment. They are following:

- The method used to build the recommender system was allowing users to set constraints for the recommender system. The recommendation module received fairly decent rating from the study participants. Usage data also suggested that the recommendation module was largely successful achieving it's goal. So, it may be concluded that users in the museum domain prefer their ability to set constraints for the recommender system.
- Visitors are inclined towards receiving recommendations from a curator. It also appears that visitors are prone towards classifying artefacts based on their cultural origin.
- Interactive features enhance the user experience on a museum tour guide. To better manage interactive features offering them based on context produces better result.
- Visitors do spend a significant amount of time on the post visit phase. Ironically, this is the phase that is least explored by researchers. Allowing a visitor to revisit their experience on this phase can improve their experience. Community engagement facility and the ability to play an expert user's role can encourage their participation.
- When interactive tools and features offered in a system, it requires longer time period for a user to better utilize the system. Once the initial learning process is over, the system is perceived to be more useful by users.

5.3 Future Directions

5.3.1 Navigation Support

The Museum Explorer was implemented a small museum. Currently, it does not provide any navigation support. The person who was running the study accompanied participants to offer navigation support during the physical tour. In larger settings, navigation support is an essential element that can significantly improve user experience. So, it will be a reasonable effort to include navigation support in museum explorer. There are some challenges implementing a navigation module in a museum. The approach should be to provide a solution that can be adopted in different types of settings.

It is important to determine if the museum has indoor or outdoor settings. In an outdoor setting, GPS system can be used where artefacts are associated with coordinates. Unfortunately, GPS does not work inside a building. Therefore, if the museum has an indoor setting a different implementation methods need to be adopted. Currently, RFID tag based and wireless network based relative positioning systems are the best technology available with fairly accurate position sensors (precision up to 1 meter). So, for indoor and outdoor settings, implementation methods would be completely different.

Position of an exhibit may change from one exhibition to another. So, it is important to find a method that offers a mechanism for the curator to change the position of exhibits. If we have the basic layout of the museum, each square foot area of the layout can be associated with corresponding coordinates (for outdoor settings). The curator should have an interface that allows him/her to place an artefact on the basic layout. The navigation module may calculate the navigation path in runtime. A similar approach can be adopted for the indoor settings.

5.3.2 Audio Visual Representation of Information

Audio visual representation of information can significantly improve the visitor's experience. Currently, detailed text based information combined with pictures are presented to visitors in the Museum Explorer. Existing artefacts in the Museum of Antiquities have one to four pictures available. If we could ensure that the system has sufficient pictures available, one could generate a video clip combining pictures and text information. An open source text to speech converter library could be integrated with the existing system to produce an audio clip from the existing text information. The audio clip can be combined with available pictures to produce video clips. Generating a video clip for each artefact can be can be carried out automatically through a script. The use of multimedia to present information could further improve the user experience.

This feature can be very useful during the pre-visit and the post-visit phase. During the visiting phase, audio clips can still be useful. But the actual artefact would be more appealing than pictures.

5.3.3 Conversation Module

Initially, the goal of this project was to interact with physical objects using attention meta-data. The museum domain was chosen due to unique properties of each artefact. The plan was to create personas in virtual space corresponding to physical artefacts and allowing visitors to have a conversation with artefacts. This ambitious goal was moderated due to time limitation. The idea of interacting with artefacts in virtual space using natural language is still intriguing. A future direction would be to construct a conversation module that would be able to handle a limited degree of conversation.

The information available with each artefact has a pattern. For instance, name of the artefact, date of origin, original piece or replica, cultural affiliations, and so on. The above mentioned pattern can be used to answer a limited set of questions. If we can generate a structure for

available information with artefacts, information can be parsed into the conversation module. The structure can be used to construct a dialog component for artefacts.

5.3.4 Improvements in Recommender System

The current approach in the Museum Explorer for generating recommendations is to allow users to set constraints for the recommender system. After the study, we have more information about users' preferences. It appears that users in this domain are more inclined towards receiving recommendation from curators. It also became evident that users in this domain have preference towards refining artefacts by cultural origin. Results acquired from the study can used to improve the recommender system.

Currently, the recommender system is not available during the visiting phase. If the navigation support is integrated into the Museum Explorer, contextual information can also be included into the recommender system. If contextual information is available, it can be very useful while generating recommendation during the visiting phase. For instance, artefacts that are located near the current location shall be receiving preference while generating recommendations during visiting phase. Thus, using contextual information an addition to the existing recommender system can be augmented exclusively for the visiting phase.

In previous chapter, it was repeatedly mentioned that the recommender system could perform better if we had more usage data. It would be difficult to specify exactly how many users should use the recommender system before it would perform up to the optimal level. A general speculation would be: the more the system is used better it would perform. Specially, the recommendation module is heavily dependent on empirical data. For instance, recommendations from similar people are generated based on the activities of a list of previous visitors who matches on background and interests with the current visitor. If we have more users, we may find better matches in background and interests. In my personal opinion, once we have more than 40 users of the system; the recommendation feature will start to perform better.

5.3.5 QR Code

Attaching QR Code to each artefact can significantly improve visitor's experience during the visiting phase. Initially, there was a plan to include QR Code to each artefact for the study. Due to time limitations, idea to include QR Code was abandoned. Since, the system was built following the Restful Architecture; it should be fairly simple to upgrade the system to incorporate the QR Code functionality.

In the AjaxRequestHandler class, a service can be included named QRCode. URL needs to be created for each artefact following the syntax bellow: http://awlad.usask.ca/museum/AjaxRequestHandler.php?QRCode=artefactid. Here, the artefactid would be a unique id created for each artefact. Subsequently, functions need to be included for each layer onwards.

5.3.6 Internet Of Artefacts

The Museum Explorer is open source software that can be adopted by any museum. It had has admin interface that can be used to load a museum collection into the system. A slight modification can make the system usable by any organization. Hypothetically, if there are multiple museums using the software; a clause under the license agreement can be included that obligate users to share their collection on the virtual space. Sharing of artefacts from various museums unwrap a possibility to create a large collection of artefacts. In other words, an internet of artefacts can be visualized where many interesting things can be introduced.

If there are multiple museums participating, various things can be done. The recommender system can recommend artefacts located in diverse geographic locations. Persona of artefacts can be created on virtual space available for interactions. Continuous interaction will generate metadata that can be associated with individual artefacts.

In conclusion, this project has enriched our knowledge about the field of computer-aided support in museums. Findings about the behavior patterns of users in this domain can be applied in a broader setting such as Informal Learning Environments. Methodologies used to improve user experience in museum settings can also be adopted in systems targeting informal learning. Improvements suggested for the Museum Explorer in the Future Directions section can be implemented to offer a better overall solution. Typically, in a museum, there are three parties involved (artefacts, visitors and curators). In my personal opinion, the biggest achievement of this project is that it encourages all parties to share their knowledge and resources with each other.

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APPENDIX A

Ethics Approval

UNIVERSITY OF SASKATCHEWAN

Research Ethics Office
NRC/PBI Building Box 5000 RPO University
1607 – 110 Gymnasium Place Saskatoon SK S7N 4J8 Canada
Telephone: (306) 966-2975 Facsimile: (306) 966-2069

To: Jim Greer, PhD
Director, University Learning Centre
University of Saskatchewan

Student: Awlad Hossain

RE: BEH 13-209

Date: October 16, 2013

Thank you for application entitled: ***User Experience Enhancement in a Museum***. It has been determined that this project exempt as per **Article 2.5 of the Tri-Council Policy Statement [2010]** which states "Quality assurance and quality improvement studies, program evaluation activities, and performance reviews, or testing within normal educational requirements when used exclusively for assessment, management or improvement purposes, do not constitute research for the purposes of this Policy, and do not fall within the scope of REB review."

It should be noted that though your project as submitted is exempt of ethics review, your project should be conducted in an ethical manner (i.e. in accordance with the information that you submitted). It should also be noted that any deviation from the original methodology and/or research question should be brought to the attention of the Behavioural Research Ethics Board for further review.

Sincerely,

Beth Bilson, Chair
Behavioural Research Ethics Board
University of Saskatchewan

APPENDIX B

Consent Form

DEPARTMENT OF COMPUTER SCIENCE

UNIVERSITY OF SASKATCHEWAN

Project Title: User experience enhancement in a museum.

Researcher: Awlad Hossain

MSc. Student, Department of Compute Science

University of Saskatchewan

Phone # 3067164177, e-mail: awh088@mail.usask.ca

Supervisor: Prof. Jim Greer

Director, University Learning Center

University of Saskatchewan

Phone # 966-2234, e-mail: jim.greer@usask.ca

Purpose and Objective of the Research:

The research involving human subjects being proposed here involves recruiting volunteers to spend a few minutes interacting with the online museum guide, to make a physical visit to the UofS Museum of Antiquities with the guide in hand on a tablet device, and to complete a satisfaction survey to evaluate how the software guide may have enhanced the experience.

Procedure:

I plan to run the study in three phases. A participant would use the system with given instruction for a short session. At the end of each session, participants shall answer few questions related to user experience. Each participant is required to spend about 45 minutes using the system. Questionnaire sessions may take another 10-15 minutes.

Potential Risks:

The study poses no risks to participants.

Potential Benefits:

The main focus of this research is to improve the visitor experience in museums or like domains.

Compensation:

Each participant will receive an honorarium in the amount of $10. They will have rights to withdraw their participation from the study at any time.

Confidentiality:

Participation in this project is voluntary. A volunteer will have right to withdraw his or her participation from the study at any point. All personal data related to that participant will be destroyed immediately upon completion of the study.

Right to Withdraw:

A participant will have rights to withdraw from study at any point.

Follow up:

A summary of study results will be available for participants.

Signed Consent:

Your signature below indicates that you have read and understand the description provided; I have had an opportunity to ask questions and my/our questions have been answered. I consent to participate in the research project. A copy of this Consent Form has been given to me for my records.

_____ _____

Name of Participant Signature

_____ _____

Researcher's Signature Date

APPENDIX C

Survey Questionnaire

Feedback Questionnaire for Museum Explorer

Enter User Name (Login ID) _____

Questions to be answered at the end of pre-visit phase

Question 1: Do you think the Tour Planner is a useful addition?

- Yes
- No

Explain Please explain if required

Question 2: Please Rate your overall experience so far (on a scale of 1-10 where 1 is poor and 10 is excellent).

1 2 3 4 5 6 7 8 9 10

Questions to be answered at the end of visiting phase

Question 3: Please Rate your overall experience so far (on a scale of 1-10 where 1 is poor and 10 is excellent).

1 2 3 4 5 6 7 8 9 10

Question 4: Are there artifacts not currently on display that you would have liked to see?

- Yes
- No

Explain Please explain if required

Questions to be answered at the end of post-visit phase

Question 5: Please rate following features of the "Museum Explorer" on a scale of 1 to 10 where 1 is poor and 10 is excellent.

Recommendation features	1 2 3 4 5 6 7 8 9 10
Tour Planner	1 2 3 4 5 6 7 8 9 10
Follow Patrons	1 2 3 4 5 6 7 8 9 10
Post-visit Summarizer	1 2 3 4 5 6 7 8 9 10
My Tour	1 2 3 4 5 6 7 8 9 10
My Favourites	1 2 3 4 5 6 7 8 9 10
Search for Artefacts	1 2 3 4 5 6 7 8 9 10
Browse By Cultural Origin (refine recommendation)	1 2 3 4 5 6 7 8 9 10
Browse By Artefact Types (refine recommendation)	1 2 3 4 5 6 7 8 9 10

Question 6: Please Explain Why you found one of above features most useful and why you found a feature least useful.

Please explain

Question 7: Please rate each type of recommendation on a scale of 1-10 where 1 is poor and 10 is excellent

	1	2	3	4	5	6	7	8	9	10
Recommendation from curator	○	○	○	○	○	○	○	○	○	○
Recommendation based on personal interests	○	○	○	○	○	○	○	○	○	○
Recommendation from similar people	○	○	○	○	○	○	○	○	○	○

Question 8: Is the notion of following other people's trails (follow patrons feature) a good idea?

- ○ Yes
- ○ No

If yes, also explain under what circumstances?

Please explain if you think Follow Patrons is a useful feature

Question 9: Compared with the static museum website, is the Museum Explorer more useful?

- ○ Yes
- ○ No

If yes, also explain under what circumstances?

Please explain if required

Question 10: Compared with the static museum website, did you find the Museum Explorer's interactive features more useful?

- ○ Yes
- ○ No

If yes, also explain under what circumstances?

Please explain if required

Question 11: Do you think that your comments and visit experience records might be useful or interest to future visitors?

- ○ Yes
- ○ No

If yes, also explain under what circumstances?

Please explain if required

Question 12: Does user involvement in community activities on post-visit phase further enhance user experience?

- ○ Yes
- ○ No

If yes, also explain under what circumstances?

Please explain if required

Question 13: This system is different from other museum e-guides because it tries to support visitors before, during and after their visit to a museum. Is it a useful innovation? Please explain why or why not.

Please explain

Question 14: Do you think your experiences of pre-visit, visiting and post-visit phases were effectively connected by the system?

- Yes
- No

If yes, also explain under what circumstances?

Please explain if required

Question 15: This prototype was developed for a small museum. What would be needed for a system like this to work in a large museum with thousands of exhibits?

Please explain

Question 16: Please rate your overall experience of using the Museum Explorer system on a scale of 1-10 where 1 is poor and 10 is excellent.

1 2 3 4 5 6 7 8 9 10

Submit Feedback