Augmenting a Museum Visitor's Tour with a Context Aware Framework

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Abstract. We present a context awareness framework to assist a Museum visitor's learning process by providing an enriched tour experience. We adapt the information a visitor receives about an artwork based on their interests and knowledge. We show how this is achievable by implementing a system that passively and unobtrusively gathers information using physical and virtual context. We also allow the visitor to visit virtually museums in different places while still benefiting from information adapted to their interests and knowledge.

1 Introduction

Museums give people the chance to look at artworks of many different forms, from prehistoric dinosaur bones to modern abstract sculptures, with the advent of the "digital tourist," [1–3, 5] museum visitors can look at an artwork and instantly have an abundance of information at their fingertips. More often than not this information will not change, additions can be made by museum staff, web-site administrators and in some cases other museum visitors [3, 5, 6] but the content displayed will still be the same for each visitor even though their level of knowledge and degree of interest are different. This paper presents a way to adapt the information received about an artwork based on what the visitor knows and where the visitor's interests lie. It describes a framework supporting diverse information requirements of museum visitors potentially ranging from children to senior researchers, and so to that end we present a way of adapting the information received about an artwork based on the visitor's interests and knowledge. The framework provides functionalities described in the following scenario.

2 Museum visitor's tour scenario

Upon entering a museum the visitor logs onto the museum network and their PDA downloads the physical layout of the museum. The visitor's itinerary and calendar for the museum are updated and the visitor is also notified of any events the system deems they would be interested in.

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A list of tour options is provided for the visitor, these tours are based on the visitor's interests, the visitor may select a tour or opt to proceed on their own. If a tour is selected an interactive map shows the visitor where to go, a digital assistant also provides directions if needed. The visitor can click on rooms displayed on the map to learn about the room's contents. During the tour the visitor can point their mobile device at a piece of artwork, this causes a browser window to open containing a small replica of the artwork. These replicas can be marked for printing as posters or postcards; the visitor picks up and pays for these after the tour. Textual and audio information regarding the artwork is provided in addition to links to similar artworks.

The visitor can choose to view additional information based on their profile. Their level of knowledge and degree of interest is taken into account when determining what extra information is displayed, for example, a visitor who considers themselves unversed in a particular form of art would receive information about the artist, the artwork's history and a general overview of similar artworks.

A user who considers themselves well versed in the same form of art would receive a detailed description of what other visitors of similar interest have noticed about the art form. Each of these techniques aims to enhance the visitor's experience by selectively adapting information to suit their profile. When the visitor has finished viewing a piece of art, the list of artworks to see in the visitor's tour is updated. The visitor can also leave comments about the artwork for future visitors as well as staff to read.

During the visit the visitor may deviate from the tour to look at other artworks, after examining similar artworks the digital assistant informs the user where there are similar artworks that previous visitors with similar interest and knowledge also found interesting. The visitor is given the option of reading why the previous visitors found the other forms of art interesting. The visitor can opt to proceed with the tour, keep browsing or look at the other forms of art the system has nominated.

When closing time is drawing near the digital assistant unobtrusively informs the user that time is running short, this allows the visitor to prioritize the remainder of their tour. After the visitor has finished their tour they can pickup any replicas marked for printing, leave comments for future visitors to peruse, they then log out.

3 Information model

Before gathering contextual information to deduce a visitor's interests and knowledge we establish a framework that addresses the way artworks and the information about those artworks are classified.

3.1 Classifying Artworks' information

Classifying artworks is a challenging problem, too little information and we cannot deduce co-locality or commonality across a set of artworks, too much information and a visitor gains no benefit from the service as seemingly unrelated

artworks overlap. We use a hierarchical approach. Storing the information hierarchically provides us with a great degree of versatility, as visitors can be interested in artwork aspects that are both broadly and narrowly defined.

Information about artworks takes on many forms of varying complexity. The museum is responsible for classifying the information held about each artwork, by ensuring an accurate mapping between a visitor's profile and an artwork's subjects we can take advantage of the semantic layer's grouping facilities to deduce a visitor's interests.

By classifying the information about the aspects of an artwork, we can accurately determine what type of information the visitor is looking for and what types of information they have accessed.

3.2 Classifying Interests

A visitor's interests must match the allowable artwork information classifications, the developed prototype updates a visitor's profile based on the classifications of the artworks seen, section 6 details how the visitor's interest and knowledge vectors are updated.

Upon entering the Museum, the user fill a registration form to explicitly state their interests and self-assessed knowledge, the form is created by the museum and is displayed as a tree-like structure, the visitor is free to select interests as broad or specific as they desire. The level of interest will be updated according to the visitor's behavior.

3.3 Classifying Knowledge

We classify the areas of interest about an artwork with the preferable level of knowledge or understanding required to gain benefit from the information. Figure 1 shows a knowledge tree as a means of representing different level of knowledge which are basic, medium and advanced.

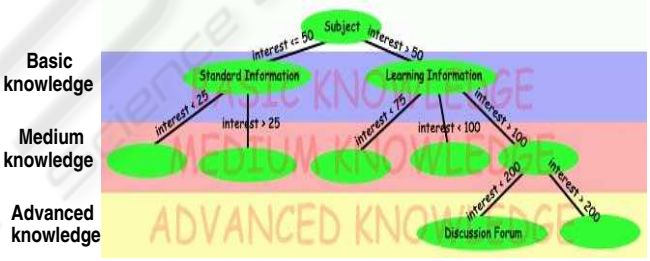

Fig. 1. A knowledge tree

We make use of this information hierarchy to select information that is only relevant to the current visitor and to prune information that the visitor would find trivial or nonsensical. The tree is traversed when information is requested,

the search algorithm takes each of the visitor's interest and knowledge vectors as inputs. For each category within the artwork's profile a depth first search is performed, each level of the tree contains more specialized or detailed information than the previous layer.

4 Conceptual Design

As a way of separating concerns and supporting the sequence of events described in Section 3.3, it was decided to adopt a 3-layered. The three layers are called physical, virtual and semantic layer as described in Figure 2.

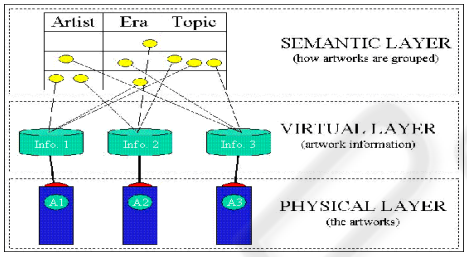

Fig. 2. The 3-layered approach

Figure 2 shows that the three artworks share the same topic. If a visitor were interested in two of the artworks then they would probably be interested in the third because we can infer that they are interested in the topic the artworks depict. We can determine what a visitor is truly interested in by their interest vectors, since each vector is updated when the visitor accesses information or looks at an artwork the subject of most interest to the visitor will have the highest vector as it is common across all instances.

4.1 Physical Layer

The physical layer is responsible for keeping track of the objects within a museum and encompasses the physical layout of a museum including all the rooms and facilities. The primary task of the physical layer is to store the physical location of each artwork.

The physical layer is usually static, museums typically organize artworks according to a fixed criteria, for example, paintings may be located in a single section of the museum and arranged in chronological order.

In our model each artwork is affixed with an infrared transmitter that continuously emits a unique identifier, this identifier correlates the artwork's physical location with its corresponding location in virtual space. Section 6 describes the mechanisms for gathering and processing physical contextual information to deduce a visitor's interests.

4.2 Virtual Layer

The virtual layer is responsible for describing the physical layer; it contains information about the aspects of an artwork that can include the artist, medium, description and links to additional information about the artwork.

The virtual layer changes as information is added remove or altered by museum staff, web-site administrators and other visitors. The pages accessed by the visitor are dynamically created according to the visitor's knowledge and interests.

4.3 Semantic Layer

The semantic layer describes the relationship between artworks and is responsible for mapping the correlation between what a visitor sees in the virtual and physical layers and what their actual interests and knowledge are. The semantic layer can logically be thought of as all the ways to group artworks by their aspects.

The semantic layer works by categorising groups of artworks. Artworks within the same group are said to be semantically co-located. An artwork can be semantically co-located with many artworks for example, Picasso paintings are semantically co-located as they share the same artist while a subset of these artworks are semantically co-located with a subset of Braque paintings as they share the same type - cubism.

The semantic layer facilitates the processing of context gathered by the physical and virtual layers by providing an easy way to determine how a set of artworks or artwork information are related.

5 Participating Entities and Roles

Our design encompasses the roles performed by three distinct entities, the visitor's PDA, the museum and the global repository.

The **visitor's PDA** (equipped with 802.11 and IrDA) is responsible for keeping track of the visitor's knowledge and interest vectors. When a PDA is pointed at certain artworks, the infrared transmitter send a URL (website address) to the device, causing a browser to appear. This allows the user to select from a range of options which might include: biographical information about the artist; a description of the process or motivation behind the artwork; or suggestions for where the visitor might like to go next. Additionally, by allowing visitor's to explicitly state their interests and self-assessed knowledge we can adequately cater for visitors wishing to expand on existing interests as well as visitors wishing to learn about a particular topic, this provides the visitor with an enriched museum tour experience. Visitor's who feel they are sufficiently knowledgeable about certain areas gain benefit faster and we overcome any frustration caused by an enforced learning curve.

The **museum** is concerned with the information management of the physical and virtual layers as well as the implementation of the semantic layer. The

museum database should at all times maintain a consistent and accurate representation of the museum and each artwork located within the museum. The types of structures used to store the museum's physical representation are outside the scope of this paper. The museum is responsible for retrieving and displaying adaptable information about an artwork to the visitor.The museum acts as a 'middleware' layer for the visitor. The museum periodically sends updates to the global repository containing each visitor's profile as well as the artworks and information they found interesting. This allows museum visitors around the world to benefit from the experiences of anyone with similar interests and knowledge instead of only local museum visitors.

The **global repository** is concerned with the information management of the semantic layer and contains visitor profiles together with information about what artworks they found interesting, information accessed and any additional comments made. The repository (multi-database) makes it possible to compare visitor profiles across museums. It accepts queries from participant museums. These queries are either search requests that return the artworks seen by visitors with similar interests and knowledge or updates to the stored data.

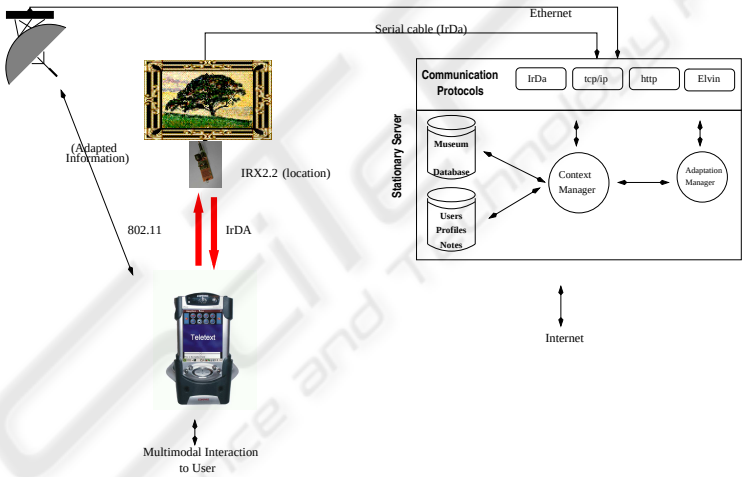

Fig. 3. Context Aware Architecture

6 Context Gathering

Our architecture is shown in Figure 3. The central piece of the architecture is the context and the adaptation managers located in the stationary network as a server. The context manager gathers and stores all information required for the adaption manager to customize the information to be delivered to the visitors.

6.1 Catering for four types of Visitor

Our system supports a diverse range of visitors. Visitors can have many or few interests, some are more knowledgeable than others. Table 1 summarizes the 4 types of visitors.

Table 1. Four Types of Museum Visitor

	Low Interest	**High Interest**
Low Knowledge	Visitors not wanting to learn or have not heard of the topic.	Visitor wanting to learn and explore their interests to develop their knowledge.
High Knowledge	Visitors with changed (diminished) interests.	Researchers within a specific field.

6.2 Gathering Context from the Physical Layer

In our prototype each artwork is affixed with an IRX2.2 infrared transmitter, the transmitter continuously emits an identifier that is received by the infrared port of a PDA. Since the interval between successive transmissions is a known constant we can know the amount of time a visitor has been pointing their device at an artwork.

6.3 Gathering Context from the Virtual Layer

Context gathered from the virtual layer represents a more accurate measurement of a visitor's interests and knowledge since the visitor is actively seeking additional information. By looking at the types of information a visitor accesses we can passively infer various things about their interests and knowledge.

When a visitor accesses dynamic information we store the current time and wait until the visitor clicks on a link or exits the page, when this occurs the stored time is forwarded together with the visitors identifier and requested action (e.g. exit, access information, logout) to an intermediary responsible for processing the virtual context, the algorithm used to process this information is provides in the following sections.

7 Context Processing

By utilizing the contextual information gathered from the physical and virtual layers described in section 5 we now present the process used to determine a visitor's interests and knowledge.

At the physical layer,we can measure the amount of time a visitor points their PDA at a particular artwork by counting the number of times the artwork's identifier is received. When the PDA stops receiving the identifier we retrieve the subjects associated with the artwork from the museum's database.

At the virtual layer, when a visitor accesses additional information about an artwork the information displayed is adapted to their profile of interests and knowledge, as a consequence we receive positive reinforcement of the visitor's interests.

This paper emphasizes using virtual context to deduce a visitor's interests, the algorithm used to update the visitor's interest vectors are weighted more heavily than those used when gathering physical context, this reinforces the theme that the quantity and quality of information a visitor accesses is a better indication of a visitor's interests and knowledge than physical context gathering.

By examining the knowledge classifications of the information accessed we can roughly determine the amount of knowledge a visitor has about a particular subject. Then we adapt the next set of information to build on the concepts the visitor has gained by classifying the knowledge content of the information displayed. We assume that a visitor accessing a dynamic page for seven seconds or more gains the relevant knowledge content and as such their knowledge vectors are updated to reflect this, we set the visitor's knowledge vector to the threshold value of the next knowledge classification.

The original prototype determined the number of seconds a visitor accessed information about an artwork and added this number to their profile for each relevant subject, this method was found to produce erroneous results as a visitor reading a single page for several minutes would have the same interest vector as a visitor reading many similar pages for a few seconds. To avoid this anomaly it was decided to classify interest periods, for instance, it might take a visitor three seconds to decide if they are interested in the accessed information, a subsequent thirty seconds will determine if they are keen on learning more and a further two minutes might elapse before we know a visitor enjoys reading about a particular topic. Using threshold values based on a time/interest curve we get a more accurate heuristic.

This value also enables us to determine when a visitor is no longer interested in a subject. Our basic premise is that when people are interested in something they tend to seek additional information about it, similarly when people lose interest in something they generally do not continue to actively increase their knowledge about the subject or do not tend to perform the activity any more.

By maintaining a list of the artworks a visitor has seen we can make further inferences about a visitor's interests when they refer back to a piece of artwork or information. We keep a count of the number of times a visitor reviews an artwork or information. At present this context is only used to create a list of artworks and information the visitor is particularly interested in, the prototype records the location of any artworks or information a visitor has visited five times or more.

8 Conclusion

This paper presents a framework that adapts the information a visitor receives about an artwork based on their interests and knowledge. We addressed the

issues involved with the gathering and subsequence processing of contextual information to deduce a visitor's interests and knowledge, we presented our design and discussed its limitations. The system unobtrusively gathers information using physical and virtual context, the goal to provide a passive framework has been achieved, after the visitor has registered they are free to browse normally while still gaining benefit from the service.

The findings of this paper are intended to be used in conjunction with pre-existing museum tour guides. Whereas the majority of the research papers examined the physical context of a portable digital assistant (PDA) this paper employs a context-gathering framework inspired by [7], we explore the concept of examining the virtual context or the information accessed by the visitor in addition to the physical context to determine their interests and level of knowledge. We currently evaluate the usability aspect of the system.

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