Adaptable, personalizable and multi user museum exhibits

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Abstract

Two dimensional paintings are exhibited in museums and art galleries in the same manner since at least three centuries. However, the emergence of novel interaction metaphors and techniques provides the option to change this status quo. By 2006, according to the Institute for Museum and Library Services, 43% of museum visits in the U.S. were remote. According to the Institute for the Future, "Emerging technologies are transforming everything that constitutes our notion of "reality"—our ability to sense our surroundings, our capacity to reason, our perception of the world". It is now the age that technology is going to be mixed to the fabric of reality within Cultural Heritage Institutions (CHis) to offer novel experiences. This work presents the design and implementation of a technological framework based on ambient intelligence to enhance visitor experiences within CHIs by augmenting two dimensional paintings. Among the major contributions of this research work is the support of personalized multi user access to exhibits, facilitating also adaptation mechanisms for altering the interaction style and content to the requirements of each CHI visitor. A standards compliant knowledge representation and the appropriate authoring tools guarantee the effective integration of this approach to any relevant context. The applications developed in the context of this research work were deployed in vitro within a

simulation space of the FORTH-ICS AmI facility and evaluated by users in the context of a pilot study.

Art, Augmented exhibits

ACM Classification Keywords
J.5 (Fine arts), H.5.1 (*Artificial, augmented, and virtual realities)*

General Terms
Design, Documentation, Human Factors

Introduction
Ambient Intelligence (AmI) presents a vision of a technological environment capable of reacting in an attentive, adaptive and active (sometimes proactive) way to the presence and activities of humans and objects in order to provide appropriate services to its inhabitants [4]. In the context of Ambient Intelligence, the need to adapt a distributed system to the requirements and preferences of a diverse user population is a major issue. This work explores the penetration of AmI technology within the domain of Cultural Heritage and more specifically CHIs through the proposal of an augmented exhibit that can either act as a standalone exhibit itself or supplementaryly to the actual physical artifact. In this context the need of personalization is important, so as to deliver the most appropriate information to visitors, thus making some form of adaptation a necessity. This work builds on and revisits the approach to UI adaptation proposed in [2, 3], so as to provide dialogue and task adaptation, content personalization and reasoning within CHIs facilitating novel means of accessing Art, and in particular two dimensional paintings.

Background & Related work
User Interface ADAPTATION
The term Intelligent UIs is defined as a novel approach to interfaces that supports more sophisticated and natural input and output, to enable users to perform potentially complex tasks more quickly, with greater accuracy, and to improve user satisfaction. The provision of these qualities within CHIs entails the need to address design issues far more complex than those faced by traditional HCI. First, there is a need to address various usage contexts and diverse interaction techniques. Second, the diversity of the target user population makes mandatory some form of user profiling and UI adaptation. Taking into account the principles of iHCI and employing the information that ambient intelligence can provide regarding the current situational context, it becomes possible to build user interfaces that employ adaptation to answer user requirements through implicit or explicit input and thus adjust the software part of the UI (single device or a distributed UI system) at runtime [5].

Formal specifications of profiles and knowledge are replacing traditional ad-hoc approaches. At the same time, rule engines are employed to facilitate adaptation logic and decision making while mature UI frameworks are employed to ensure a smooth user experience.

Interactive Exhibits and Personalization in CHIs
Nowadays CHIs strive to design and implement interactive exhibitions that offer enjoyable and educational experiences. However, designing such an exhibition is not an easy task mainly because: (a) most visitors might visit only once, and (b) a typical visit only lasts for a very short time [6, 7]. Interactive exhibits can be broadly classified in four categories: (a)

hybrid exhibits which aim at augmenting an artifact with graphics [8]; or audio commentaries [9], (b) side exhibits which are placed adjacent to a real exhibit, providing indirect exploration of, and interaction with, it [10], (c) isolated, but linked, exhibits having “a conceptual affinity with the original artwork”; they are related to a real exhibit but installed in separate, dedicated, locations [9, 11] and (d) stand-alone exhibits containing content related to an exhibition, but not directly linked to an artifact[12].

Museum Mobile Applications

Mobile devices have currently achieved the greatest amount of penetration within CHIs. Existing mobile applications for CHIs fall into the following categories [13]: (a) 45% provide guided tours of the CHIs in general, (b) 31% provide guided tours of temporary exhibitions, (c) 8% provide combinations of the first two, (d) 8% are applications devoted to a single object, (e) 4% offer content creation or manipulation and (f) 3% are games.

Contribution of this research work

Although much work has been done to date, there are several limitation to the approaches currently followed for facilitating CH within CHIs. Major improvements are considered: (a) the support of multi user interaction, (b) content personalization, (c) facilitation of structured knowledge (based on existing domain standards) and (d) scalability and extensibility. To provide these qualities the augmented digital exhibit was designed and implemented to be: (a) generic build on top of an ontology meta-model (extending CIDOC-CRM) to present two dimensional paintings including the appropriate tools to support the integration, annotation, and preparation of knowledge, (b) a full featured multi user exhibit that can be access by a great number of visitors concurrently (using smart phones, digital projections, interactive captions and hand held tablet devices), (c) personalizable using mobile devices for information displays but also to fill-in user profile so as to adapt content and presentation and (d) Adaptable facilitating a rule engine to execute UI adaptation rules resulting to the optimum UI variation for each user.

Scenario of use

One of the personas used during the conceptual design of the exhibit was Anna that has a non-professional interest in art, but surely an art lover enjoying visiting museum, galleries, etc. Anna decides to take a visit to the local museum of Art. While entering the museum towards the exhibition, a notification appears on her mobile device prompting her to download the mobile client. She also takes a minutes to fill in an anonymous profile. Within the museum her mobile device is used as a navigator allowing her to access information by scanning QR codes. When Anna approaches an exhibit, she notices that information is projected on the periphery of the painting, while a tablet is unobtrusively located in front as an interactive caption. Anna can use touch for navigating and browsing the vast collection of information available for the specific exhibit using the tablet. She also shows the QR code representation of her profile to the caption (or any other component of the exhibit) so as to access personalised information (Anna has painting as a hobby and loves learning about materials and techniques used by the old masters). She also notices that the UI of the caption is altered allowing her to slide through representations (as an expert user of mobile devices). When she stands in front of the digital painting, an interactive menu appears allowing her to start interacting with the specific exhibit. She can use her hands to indicate points of interest within the painting to get information regarding the selected points of interest. She can also use gestures for zooming in and out specific regions of the painting and therefore accessing details that are typically lost when digitized artefacts are presented in their entirety at low resolution. Anna also wonders what happens when more than one person is accessing the same exhibit. In the room she sees several people standing in front of a large painting and all seem to be actively engaged while also noticing that an elderly user is required only to locate himself in front of a painting so as to get information. Alternatively, when approaching a physical exhibit she get informed that she can use one of the tablets located on a stand on each side of the exhibit to access personalised information based on her location in front of the painting.

A Distributed Architecture to support content and UI adaptation in CHIs

Four main goals are addressed in the proposed architecture (see figure 1): (a) model the knowledge facilitated by the system (artefacts, users and context), (b) provide facilities within a distributed environment (consisting of applications, devices and sensors), (c) provide personalised information to users based on their preferences and (d) perform task and UI adaptation.

The Content Personalisation Engine (figure 1 section A) employs the Art meta-model, which is an extension of the CIDOC CRM [16], to represent two dimensional paintings. The model is populated with the help of an authoring tool developed in the context of this research work and currently contains 300 paintings by 30 world known artists. The authoring tool targeting to curators enables the documentation, annotation and orchestration of the way that digitised artefacts are presented. Additionally, the User Profile model of the engine contains attributes used to personalise information to visitors. These models are exported to the higher levels of the architecture through a set of programming language classes (c#, java protégé data export facilities) and two sparql query (c# using SemWeb.Net and java using Jena and Pellet). Finally, the multi-scale image repository stores and serves through an IIS web server images in extremely large resolutions and their representation in xml so as to be used for deep zooming into digital artefacts.

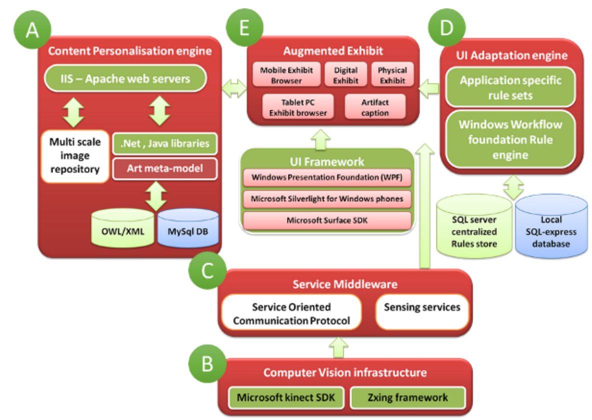

Figure 1. Abstract service oriented architecture

The Computer Vision Infrastructure (figure 1 section B) is built on top of the Microsoft Kinect SDK to support a number of alternative interaction styles (hand - skeleton tracking, gestures and postures recognition). At the same level lies the zxing library for generating and scanning of QR codes. The service oriented communication protocol (figure 1 section C) built on top of the FORTH's Famine middleware [15] (a distributed service oriented middleware), provides a common dialect for applications to coexist and communicate in the context of the developed application scenarios while using sensing for decision making.

The UI Adaptation engine (figure 1 section D) has the responsibility of producing adaptation decisions using the Windows Workflow Foundation Rules. For each application a set of rules has been defined. These rules are modeled separately from the interface itself and the adaptation engine carries out the task of chaining an interactive application with its rules and user profile so as for adaptation to be performed.

Finally the Applications (figure 1 section E), which extract functionality from services, are targeted to different devices and application frameworks and are interconnected at runtime to form personalized application scenarios.

The Augmented Personalised Exhibit

The Augmented Personalized Exhibit provides interaction where no interaction exists (making physical artefacts interactive) and provides interactive digital artefacts where no artefacts exist (importing both an artefact and the means to interact with it within the CHI experience). To do so this research work builds on the creation of a personalized digital/physical exhibit that comprises a number of devices for content provision as long as a number of modalities for interaction. As show in Figure 3 the main section of the exhibition wall is occupied by a digital representation of an exhibit in two variations. The first variation is a fully digital exhibit where the exhibit itself is projected through the usage of a short throw projector while the second one is an actual physical painting. In both cases skeletal tracking technology is installed on the exhibit for tracking the location and distance of visitors. The installed tracking technology supports the presentation of information about points of interest using body tracking (two visitors supported on the body tracking mode while three are supported for the hand tracking). At the same time on the rear sides of the exhibit two tablets are mounted on the wall or on two portable stands to act as the captions of the painting. The captions based on the visitor profiles present a multitude of information such as description, videos, points of interests, deep zoom representation of the painting, full artefact info and information from external sources. These tablets are also equipped with embedded web cameras for QR code recognition. Visitor mobile phones are used for accessing information about the exhibit by scanning the QR codes (from the captions). Portable tablets, rented or carried by visitors can be also be employed as information displays.

When augmenting physical exhibits, technology should be non- intrusive and thus it is necessary to use side displays for presenting information about the artefact that are activated on demand, or alternatively rely on mobile devices for presenting information.

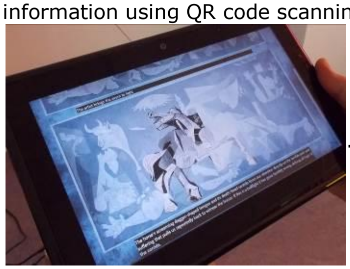

Figure 3. Augmenting a Digital Exhibit

Content Personalization and UI adaptation

The content personalisation workflow is initialised by the installation of the mobile client to a visitor's cell phone. When the application launches, the user is prompted to fill-in an anonymous user profile. User selections are stored in the smart phone's local storage.

This profile is used for presenting personalised information from the smart phone. To do so all queries formed by the mobile application to the ontology model carry with them the required profile attributes and the QR code of the exhibit scanned by the user. Users can use the mobile client to generate a QR code representation of the profile that is in turn scanned by other interactive applications so as to identify user preferences. For example, the user can shows the QR code generated from his mobile phone to the mounted caption or the exhibit itself, and the exhibit personalises the information to the profile selections of the user. In the case of UI adaptation, each interactive application comes to its initialisation state by retrieving and executing the application specific rules from the rules store. A QR recognition service is initiated and runs on the background. Each of the users can in turn use their Smartphone to generate the QR code representation of their profile, and point this representation to the application so as to transfer their preferences to the application. The transmitted preferences are used to alter several application properties. This results in the re-evaluation of the rules by the rule engine and the generation of adaptation decisions. These decisions are used to generate an adapted UI that matches user preferences.

Deploying the exhibit in vitro

In the context of this research work a room within the FORTH's AmI facility was properly prepared so as to host the digital exhibit.

Evaluation

The strategy followed was initially to evaluate the augmented digital exhibit with usability experts to identify usability problems and then perform a larger scale user-based evaluation. The expert based evaluation was conducted by three usability experts. A scoring scale from 0 (not a usability problem) to 4 (usability catastrophe) was used [14]. Thirty issues were identified in total, and twelve of them were considered major usability problems. The user-based evaluation session was performed within an in vitro instantiation of the exhibit with the participation of ten users. Users were requested to fill in a pre-test questionnaire containing demographic information and questions to collect data regarding the attitude of the user population towards CHIs and the usage of ICT technology within CHIs. Upon completion of this process users were requested to carry out a number of interaction scenarios and then fill in the post-test questionnaire. User interaction was recorded for offline processing.

The analysis of the **pre-test questionnaire** shown that 60% of the users visit a CHI once a year, 50% declared their interest in painting but only 10% follow some specific art styles or trends. More importantly, 50% of the users have visited in the past a CHI with some form of interactive exhibits. Regarding their satisfaction from CHI visits, 90% are not satisfied from the information gathered, while 60% feel that CHIs are boring due to this fact. To overcome this issue, 10% have hired in the past a guide and 50% an audio guide. 80% of the participants had experience with other forms of interaction in addition to computer and mouse.

The results gathered through the **post-test questionnaire** were used to calculate four factors. The OVERALL factor expresses the overall user satisfaction. The SYUSE factor measures the satisfaction of users when using the system, while the INFOQUAL measures the quality of information. Finally, INTERQUAL is a factor that captures user satisfaction regarding the interface of the system. The OVERALL factor shows that ~87% of the users are within the range 5 to 7 while 30.56% of the users provided a grade of 7 to all questions. However, ~5% of the users stated that they were not satisfied. According to the SYUSE factor ~85% of the users are within the range 5 to 7 while

~37% of the users provided a grade of 7 to all questions. However, there are ~14% of the users that state that were little to medium satisfied. Regarding the INFOQUAL factor ~88% of the users are within the range 5 to 7 while ~25% of the users provided a grade of 7 to all questions. However, ~43% of the users scored 6, which implies that there is a substantial amount of users who faced some form of difficulty understanding the presented information. The INTERQUAL factor shows that ~83% of the users are within the range 5 to 7, while ~35% of the users provided a grade of 7 to all questions. However, ~25% of the users that scored 5 and ~24% that score 6, which implies the existence of some form of usability barriers. These results provided some initial indications about potential improvements. To identify those areas an in depth post processing of the questionnaire data was conducted. The questions where grouped into four categories, analysed both individually and by category:

- **General User Satisfaction:** Regarding the general user satisfaction ~22% of the users score a medium satisfaction while also ~66% of score 6 while only ~11 are fully satisfied. These results also empower the need of further investigation to identify areas of improvement.
- **Interaction metaphors:** The hand tracking interaction metaphor scored lower grades in relation to body tracking and touch (~55% of the users scored 5 regarding hand-mirrored hand synchronizations and ~44% scored 5 into hand based content navigation). On the contrary, body tracking and touch have better results.
- **Information representation & extraction:** Users were in general very satisfied (~85% scored from 5 to 7 in all questions). Nevertheless there, is a percentage of ~55% who are not fully satisfied regarding the way that information is browsed in general. In this sense 33% scored 5 the way that information is presented using body tracking, ~44% scored 6 for the mobile client, while ~55% scored 6 in the caption.
- **UI Adaptation:** Regarding the ways that the UI of the system are adapted, users were in general satisfied (~70% scored from 5 to 7 in all questions), but ~30% of users were not fully satisfied with the mapping of adaptation action to their selected profile.

Discussion & future work

This work expands the current SoA in the context of augmented exhibits within CHIs in a number of directions. The proposed digital exhibit integrates a number of alternative devices and interaction metaphors to facilitate simultaneous multi user access to Art while also providing the appropriate tools for curators to document, annotate and orchestrate the presentation of artefacts. Moreover, focus is put back to Art itself rather than providing just another exhibit in the CHI. In the same context visitor's interaction capabilities, technology expertise and art knowledge are facilitated to personalise content and adapt UI copping with the diversity of the target user population. Finally, user acceptance and satisfaction factors were measured by conducting a user based evaluation within an in-vitro installation of the proposed approach. Regarding future improvements, the first step is the improvement of the exhibit based on the feedback received by users while also acting towards the practical exploitation of the concept within CHIs. The framework itself can be employed not only for presenting digital artefacts but also engaging Artist into creating novel interactive digital artefacts that combine

Digital Art with alternative interaction metaphors. Finally this work could be extended to support a form of digital personalised art catalogue. Visitors using their mobile phones can access information about artefacts and download them to form their own printable Art Catalogue.

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