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Personalizing Virtual and Augmented Reality for Cultural Heritage Indoor and Outdoor Experiences

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Abstract

Most cultural heritage exhibitions, both indoor and outdoor, could benefit from context-aware and personalized museum guides. Although, technological advancements in digitization, digital storage, visualisation and interaction have evolved rapidly, the current generation of museum exhibition and mobile guides offer systems with restricted capabilities and content, for example user selected audio guides and interactive touch screen kiosks. This paper presents solutions for both museum exhibitions and mobile guides moving towards a unifying framework based on open standards. This can offer more customisable experiences attracting and engaging a broader spectrum of users. Our solution takes into account the diverse needs of visitors to heritage and mobile guide exhibitions allowing for multimedia representations of the same content but using diverse interfaces including a web, a map, a virtual reality and an augmented reality domain. Different case studies illustrate the majority of the capabilities of the multimodal interfaces used and also how personalisation and customisation can be performed in both kiosk and mobile guide exhibitions to meet user needs.

Categories: Virtual and augmented reality, personalized heritage visits, mobile guides, location-aware.

1 Introduction

Museums and other cultural institutions try to communicate the theme of their exhibitions and attract the visitors' attention by presenting audio-visual information in a number of different ways. As a result, traditional museum exhibitions have evolved from passive presentations of artefacts to interactive displays, such as pre-recorded audio guides and static information kiosks [VI*02]. However even if some technological advances have been adopted by current museum and mobile exhibitions, they provide very simplistic presentations compared to the potential of the current Information Technologies. Occasionally, experimental prototypes have emerged from universities and research institutions but there is still need to offer support to cultural heritage exhibitions mainly because the resulted prototypes are too complex for the visitors and thus can not meet their needs. It is therefore essential to provide a unifying framework that can be highly customisable, user-friendly and intuitive to use in order to engage a broad spectrum of users and take into account the diverse needs of museum visitors. The proposed framework is focused on open-standards for easy adaptation of content and presentation across different media and hardware including desktop and portable devices.

For indoor exhibitions, some of the most characteristic technologies will be presented to demonstrate how multi-modal presentations and interactions of three-dimensional heritage environments can provide enhanced support in practice. Examples from virtual museum exhibitions are combined with virtual and augmented reality collections of artefacts through the use of a web-based interface. Initial user studies concluded that new technologies like virtual and augmented reality can be used successfully within museum environments [LA*03]. They are in effect empowering tools in the hands of the experts working towards ensuring that the museums' goals materialise successfully not only because of their popularity, but also because they offer an innovative, appealing and cost-effective way of presenting cultural information and provide an enhanced experience to the virtual visitors. However, it is essential to introduce personalization in virtual museum exhibitions to provide the users with a variety of options, offer accessibility for

people with special needs, like the disabled and elderly, and permit them to choose according to their preferences and desires. The information provided shall not be the same for all. Specific interests and characteristics of various user groups must be taken into consideration and allow creating usable, useful and attractive applications with differentiated access to information and services according to the visitor profile.

On the other hand, for mobile personalised applications like on-site visits, a highly customisable mobile framework illustrates how personalized visits to open-air heritage sites can be performed. Navigation within the open-air locations is based on the calculation of position and orientation information through global positioning system (GPS) and digital compass respectively. Presentation can be delivered in a two-dimensional domain (digital map), a three-dimensional domain (VR map) or an augmented reality domain (textual information). These tools can provide an intelligent mobile guide, allowing users to define routes through sites that best satisfy their information needs, and take account of their declared interests to ensure that they do not miss any particular exhibit. Users can perform advanced searches that take into account spatial location and personal interest. Users can also act as generators of content, adding placemarks that can be shared with other visitors using any of the above visualization domains. Evaluation as part of the LOCUS project [Loc*08] indicates that the combination of three-dimensional information has a beneficial impact for users engaged in the tasks of navigation and exploration.

The paper is structured as follows. First, an overview of the information needs is presented including both museum user needs and mobile user needs. Moreover, the challenges for personalisation in museum environments and heritage institutions as well as an overview of the most characteristic cultural heritage exhibitions and mobile guides are provided. After that, the architecture of the proposed multimodal customisable framework and each major component (kiosk environments for museum environments and mobile guides for outdoor exhibitions) are briefly explained including the technologies used. Finally, for each category two case studies including initial evaluation results and the conclusions drawn from the undertaken research are illustrated.

2 Information Needs

2.1. What are the current museum user needs?

Current researches have shown that the World Wide Web enhanced by 3D visualization tools such as the promising virtual reality (VR) [PC*00] that signifies a simulated environment created by a computer that a user can get interact with or manipulate it, Augmented Reality (AR) [Lia07] that signifies computer generated 2D or 3D virtual worlds superimposed on the real world and Web3D technologies may facilitate the preservation, dissemination and presentation of cultural artefacts in museums' collections [LA*03]. As stated by MacDonald and Alsford [MA97], "*…museums cannot remain aloof from technological trends if they wish to attract 21st century audiences*". The availability of these advanced technologies creates new opportunities for enhancing the museum experience. Museums explored these new possibilities and consequently shifted their interest from the objects of their collections to the users' needs; they become more user-centred than collection-centred. In order to create meaningful and engaging Virtual and Augmented Reality experiences for Cultural Heritage Indoor and Outdoor applications the museum user needs for interactivity, accessibility and learning must be taken into account.

Interactivity has been defined as explorative, manipulative, and contributive [PP01]. A virtual museum exhibition tends to be more dynamic and interactive rather than static in nature and authoritative [Wor97]. According to research the key features of an online interactive exhibit are: (a) *multiplicity of contexts for the users to connect with the exhibit in a seamless manner*, (b) *good instructional design*, (c) *pro-active learning contexts*, (d) *good balance between learning and leisure* and (e) *no text-heavy pages to interfere with the learning experience* [TSA03]. Interactivity enables participation of the users that are not anymore passive viewers of static exhibits, but are transformed to participants of the museum experience by use of interactive interfaces. Museum visitors use and interact with the virtual museum environment via a constructive dialogue that provide them with access to thematic information and explanations about the museum objects' context with the level of information and the amount of detail they prefer. They shift their focus from the high-quality presentation of collections to the making of meaning from the artefacts and their interpretation. Interactivity can also provide a strong effect upon conceptual learning that is connected with the deeper transferable understanding of abstract knowledge and the logical thinking, the formation of stories, concepts, associations, perspectives and strategies [Gam01], [RS05].

Web technologies with their ubiquitous and global nature can enable access to virtual museum exhibitions to anyone from almost anywhere beyond national and cultural barriers. They are used not only because of their popularity, but also because they provide an enhanced experience to various user-groups of virtual visitors. They can provide accessibility to virtual visitors including elderly people with functional limitations, people with physical impairments, such as people with visual, acoustic, learning, speech and motor disabilities that according to the Disability Discrimination Act (DDA) people have equal rights of '*access to goods,*

facilities and services' [DDA08]. The increased efficiency of Internet connections makes it possible to transmit significant media files for content-rich virtual exhibitions in a multimodal way with user-friendly, high quality presentations in an innovative appealing and cost-effective way. By combining the capabilities of multimedia technologies, web-based systems can become a powerful communication channel that may be a virtual '*direct*' experience. They can disrupt linear sequences and provide usable and accessible in technology, content, navigation solutions for all people, irrespective of their age or abilities. However, there is a constant need for virtual museums to reach out and attract larger and more diverse audiences and find ways to understand visitor expectations and experiences, address the needs of diverse user groups and be responsive to various communities' interests and needs. Museums can be considered as educational institutions that contribute to informal learning. Their effectiveness relies on the ability to convey information in an engaging way, communicate information about the museum artefacts context, since Falk and Dierking [FD00] define learning in terms of how users are able to comprehend the presented information.

2.2. What are the current mobile user needs?

When considering the information needs of a mobile device (i.e. users visiting cultural heritage sites) the information needs of mobile users should be taken into account. Users of portable mobile devices are quite distinct from their desktop counterparts [MM07]. Whilst desktop users tend to work in a familiar, static environment, mobile users tend to explore dynamic, often unknown environments. Mobile users are more likely to be distracted by this external environment, and to be interacting with it, for example navigating through it, or finding out information about it. This external influence places a load on the mobile user, which may reduce his/ her capacity to assimilate information from the mobile device. Research has shown that mobile users have a different pattern of usage when compared to desktop users [ADN08]. This also offers an opportunity for mobile computing: the device can retrieve information relevant to the physical environment while the user is moving, and provide assistance to satisfy the information needs.

Whilst desktop usage is characterised by a small number of long sessions per day (often for hours at a time), mobile users access their device more times per day, but each session tends to be just a few minutes in duration. Mobile devices present constraints in terms of hardware. They have smaller screens, leaving little room for the visualizing information. These factors suggest that there is a need to filter information for mobile users, to reduce the quantity of information presented, and ensure that only the most relevant information is presented [MM07]. One approach to filtering information is to ensure the information is personalised, to take into account of the preferences of the particular user. An alternative strategy is to filter information according by spatial proximity to the user, to make sure that it is relevant to the device user's current physical environment. A study conducted as part of the WebPark EU project [Mou05] suggests that 50% of mobile individual's queries have some spatial component, most frequently linked implicitly to their current location. These queries tend to be characterised by people asking questions such as 'What is this?', 'What is the way to…?' and 'Where do I find…?'.

3 Personalisation

Personalization, an important design element [Mat97], is the ability of a virtual museum system to alter and customize its output environment according to the characteristics of the various user groups. Its importance is widely recognized by museums [RAS06]. This process especially useful for web-based applications has the potential to target various user groups, provide efficient access to virtual museum information and offer an experience in line with the different user's age, interests, background knowledge (expert, student, tourist), computer knowledge, educational background and life-style, motivations, language skills, special needs, different bandwidth constraints.

The information provided to the user through any of the above techniques can be adapted at three different levels: content, navigation and presentation [BN04]. Personalized systems help to recreate the human element that '*listens to the visitor*' and '*understands him*' by offering a personal touch; the museum monologue turns into a dialogue [BF04]. In addition to this, personalization improves the usability of the virtual museum environment, because it provides to visitors the ability to interactively choose their preferred style of navigation, to determine the order of presented information and an in-depth search by demand. Thus, it encourages the involvement and allows them to actively participate to the virtual museum experience, strengthens the visitor's ability to explore and reduces the time and effort to find relevant information. Besides this, it improves the comprehension and facilitates the critical thinking and the meaning-making. There are two ways to collect data for personalizing virtual museum interfaces including *explicit* and *implicit* data collection.

In explicit data collection, the virtual visitors can manually submit information about their preferences and interests by various ways (e.g. fill-in questionnaires; ranking). This method provides "high quality" profile information, but spending time and effort for submitting data sometimes discourages users [KFM*04]. On the other hand, in implicit data collection, virtual visitors preferences are extracted from monitored interactions

with the system (e.g. web usage mining; cookies; collaborative filtering; visits to links; time spent for viewing it; image zooming; accessing by search). The advantage of collecting profile data this way is that the user is relieved of the burden of having to supply and keep up-to-date the necessary information. However the data that come from implicit methods are considered as of "lower quality" than data extracted from explicit methods [Nic97]. Implicit measures and explicit ratings can of course be used in conjunction with one another to provide a more accurate user profile [KT03].

The most common methods for analyzing the data for personalizing virtual museum interfaces include: (a) *content-based methods track user behaviour and preferences*, which are based on the common features of the content a virtual museum user visited and recommend items with similar characteristics, (b) *collaborative filtering methods* [Nic97], [MCS00] that compares user's preferences with those of others to personalise based on the behaviour of other similar virtual museum users, (c) *rule-based filtering methods* that create rules based on static or dynamic profiles to affect the content provided to a virtual museum user [MCS00] and (d) *web usage mining* which is used in virtual museum websites and uses statistical and data-mining methods to the Web server log data, to specify patterns of users' navigational behaviours [BF04].

4 Multimodal Framework for Heritage Guides

Multimodal interfaces are relatively new types of communication between users and computing systems. They cay vary greatly depending on the delivery method as well as the interaction techniques employed. This section presents the adaptable architecture, which is based on common technologies and can be adjusted according to the application as well as the user needs. Our personalised heritage solution uses the capabilities of client-server architectures with two basic elements: the information server and the client, which are in essence the two multimodal heritage systems (kiosk or mobile guide). The information server holds multimedia objects, such as metadata and textual information, images and maps, 3D models [Loc*08], [Arc*08]. However, the description of the server side is out of the scope of this paper and the emphasis has been given in the multimodal client systems and the way they present information to users. Figure 1 illustrates the personalised multimodal framework that provides customisable solutions for both indoor and outdoor heritage exhibitions.

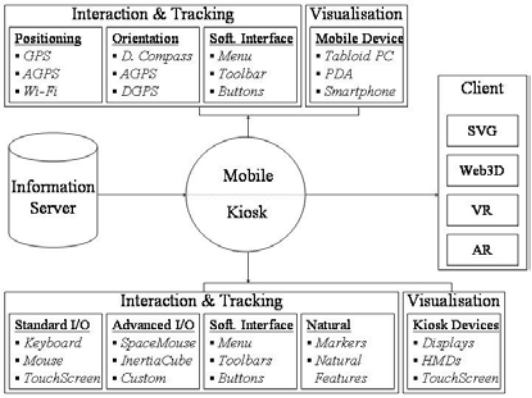

Figure 1: Personalised architecture for both kiosk and mobile heritage exhibitions

Each multimodal system is based on a different software and hardware infrastructure for presenting customisable content to users in a compelling and intuitive manner, but both systems use open standards. The kiosk system is focused for museums and other heritage exhibitions that want to give the freedom to their visitors to choose the information (i.e. galleries, artefacts) they want to visualise and interact. The mobile guide is designed for visitors than want to perceive location-aware information (maps, routes, etc) anywhere and anytime using accurate position and orientation information. A brief description of both systems is provided in the next two sections.

4.1. Kiosk Framework

There are many museums throughout Europe that hold archives of various-sized artefacts which they cannot exhibit in an efficient and low cost manner. Multimodal kiosk interfaces for museum environments and other indoor exhibitions can be exploited effectively to offer several different and interesting types of exhibitions [WP*07]. The main advantage over static kiosk presentations is that multimodal technologies allow users select depending on their preferences or needs to switch between three different types of visualization and interaction environments. A highly customisable and adaptable framework for such environments was derived through some of the results of two EU projects [Arc*08], [Epo*08]. The aim of the kiosk framework is to provide customisable solutions for virtual cultural heritage visualisation and interaction so that it can meet diverse user needs. An overview of some of the most characteristic technologies employed in the multimodal mixed reality kiosk system is presented in Figure 2.

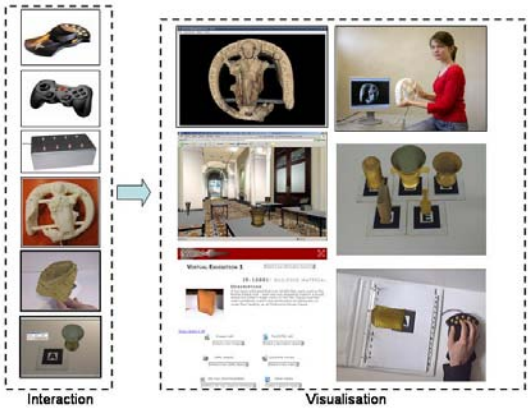

Figure 2: Kiosk framework [WP*07]

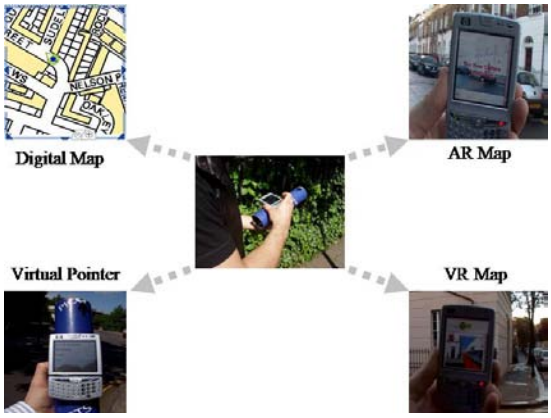

Figure 3: Mobile framework

The multimodal kiosk interface allows visitors to select the best visualization mode for a particular application scenario. The fundamental idea behind this is based on the concepts of two previously implemented separate interfaces: a multimodal interface for safely visualizing museum artefacts [WP*07] and an interactive Web3D/AR interface for virtual museums [Lia07]. The seamlessly integration of these interfaces allows users to transfer 3D artefacts together with metadata over the internet and superimpose them on an indoor AR environment as well as interact with the artefacts in a number of different ways using several types of interaction device. Integrating the two systems together can easily be achieved by treating them as two separate but communicating interfaces through the use of XML technologies.

4.2. Mobile Framework

The mobile framework uses the capabilities of the LOCUS system [Loc*08], which was developed on top of a mobile platform specifically designed to provide digital guides for tourism [Cam*08]. The novelty of the system is that it allows users to switch rendering modes between the traditional digital map guide, a virtual guide and an augmented guide. This allows mobile visitors to select the most appropriate presentation type according to their needs. Additionally, the system provides both position and orientation tracking in mobile devices operating anywhere in the word. A high-level architectural diagram illustrating the major visualisation domains taking place in the mobile multimodal guide framework is presented in Figure 3.

As the user navigates inside the urban environment, the position and orientation is consciously computed from external hardware devices such as GPS and digital compass and the camera pose is updated respectively. Then depending on the user needs, a map and/or a virtual reality interface presents two different navigation options. The mobile guide uses client-server technologies and it specifically designed for mobile devices such as PDAs and smartphones. The main objective of the multimodal system is to provide location-based services to mobile users delivered through a web-browser interface (i.e. Pocket Internet Explorer). In terms of functionality, it offers software libraries for integrating positional and orientation information, via Bluetooth, to provide navigational information about the surrounding environment as well as 'mobile search' options.

5 Case Studies

5.1. Kiosk Guide

In terms of presentation, the multimodal kiosk offers a web domain in the traditional way, a web3D domain, a VR domain and an AR domain. This allows users to select relevant information and combine it into the same presentation environment. To test the functionality of the web-client, two virtual museum exhibitions have been designed: one for Sussex Past respectively and another one for Victoria & Albert museum. The web client is a customised web-browser interface, which communicates with server visualise the heritage repository. The retrieved digital content can be rendered initially on the web browser and then on the AR tabletop environment.

The VR domain consists of two approaches: one using pure VR and another using web-based VR. The pure VR solution can operate as a stand-alone component and can work within a museum environment in a dedicated PowerStation. On the other hand the web-based solution takes advantage of the client-server functionality and

can access heritage information not only from a museum environment but from user's homes. The differences between the pure VR solution and the web-based solution are in realism, accessibility and personalisation. The latter can take advantage of the latest communication technologies (i.e. broadband, WiFi, etc) and provide a web-based VR presentation that can be accessed from anywhere and at anytime. In addition it very easy to customise and personalise the content of the VR-based presentation since everything is controlled via server technologies. However, because the underlying technology used for rendering is VRML, it lacks of advanced rendering capabilities and thus realism. On the contrary, the pure VR solution, offers a much better representation of the virtual artefacts because it uses computer graphics algorithms for the generation of soft and hard shadows, reflections and advanced lighting and texturing techniques [Lia07].

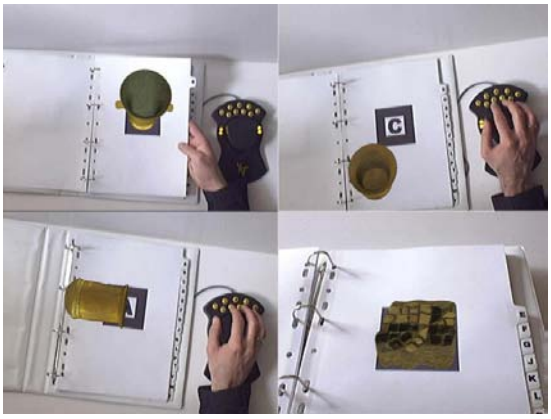

Figure 4: Kiosk AR presentation [Lia07]

In Figure 4, users can manipulate freely the marker cards in 3D space to receive a different perception of the AR exhibition. By using the configuration setting of the collaboration in the AR interface, visitors can use HMDs and obtain a completely immersed view. In a different customisation, users can see more than one object in the kiosk environment. This can be easily achieved by just adding another marker into the kiosk and augmenting another 3D object on it. The augmentation can be extended to as many markers as long as the camera can detect them within the optical field-of-view. It is worth-mentioning, that the realism of the visualisation highly depends on the 3D modelling procedure. Also, one of the most important goals of modern archaeological applications is to present museum artefacts in a more attractive manner such as in an AR environment. In this way, museum visitors and especially small children could become more interested in cultural heritage.

A combinatory usability evaluation, in which participated museum curators, as domain specialists and end-users representing the museum visitors, has been undertaken to investigate the educational and entertaining experience offered by the kiosk system. Qualitatively analysis grouped the evaluators' comments into the main categories of positive comments, usability flaw characteristics and remarks/suggestions [SE*08]. For the usability evaluation of the system two approaches have been employed: a questionnaire-based survey and a Cognitive Walkthrough session by museum curators as domain experts and usability experts. Cognitive walk-through methods [Nie94] involve the 'walk-through' of a number of tasks, exploring the systems' characteristics, locating and identifying potential problems and their causes. The research results uncovered the usability problems of the interface and compared the assessments of the two different evaluators' groups concluding that in complex interfaces double experts (usability and domain experts) are inevitable for reliable and valid results [SE*08].

5.2. Mobile Guide

A location-aware mobile cultural guide was implemented in the Swiss National Park: Switzerland's only National Park, and a site of great natural and cultural importance. Visitors are attracted to the dramatic, mountainous scenery, the rare flora and fauna, and the history of human influence on the park. In this case study, the map was chosen as the primary interface for the system, and all information stored in the information database was spatially-referenced, allowing it to be placed on a map, relative to the device user's location.

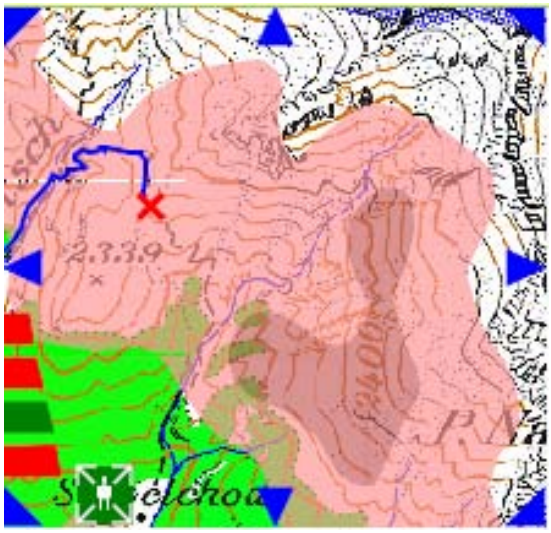

Figure 5: Distribution of red deer (darker brown, more likely to find red deer), relative to user's current location (the red cross)

To allow visitors to access general personalised maps, information was structured according to the activities that visitors participated in (e.g. hiking), frequently

asked questions about facilities and access (service / tips), visitors' main interests (fauna and flora, habitats) and other themes, based upon current exhibitions at the park. By drilling down into these categories and choosing to display the information on a map, the visitors could generate a bespoke map based upon their personal interest and current location, for example, the locations of the sites of lime kilns in the park, the extent of the range of red deer, or places where the flower, edelweiss, is likely to be found.

An evaluation study of the system was conducted with 87 participants in the Swiss National Park. Selected visitors were provided with a mobile guide on arrival at the Park information centre, given brief instructions on its use, and asked to return in the evening and fill in a questionnaire assessing the usefulness of the mobile guide [KA04]. The main strength of this method was the adaptability of the testing scenario since the mobile guide was used in the field as required, unsupervised without any intervention from the project team. On the contrary, the main flaw was that it could not be guaranteed that all users would utilise all of the system functionality.

Overall the user reaction to the guide was very positive. Considering the quality of the information presented by the device, three-quarters of people rated this as either 'very good' or 'good'. Some two-thirds considered the ease of information provision to be 'very good' or 'good'. Crucially, the approach of personalising the information presented to the user by filtering it according to the user's position appears to have been a valued strategy: over 40% of participants considered this filtered information retrieved to be 'very relevant' compared with 12% when the information was unfiltered. As an example, the 'search around me' filter was provided the most relevant information with two thirds of the respondents saying that this provided 'extremely relevant' results, and over 90% claiming that results were either 'extremely relevant' or 'relevant'. . Finally, presenting information over a map appeared to meet the needs of visitors: 85% of participants found the maps showing information retrieved following personalised searches to be 'beneficial' or 'very beneficial'.

6 Conclusions and Future Work

This work has presented how personalisation of mixed reality multi-modal interfaces can be used for targeting the needs of visitors for both kiosk exhibitions and mobile guides. We showed the importance of a unifying framework for heritage exhibitions especially if it can be highly customisable, user-friendly and intuitive to engage a broad spectrum of users. The proposed framework is focused on open-standards for easy adaptation of content and presentation across different media and hardware including desktop and portable devices and takes into account the diverse needs of visitors to exhibitions. The multi-modal functionality allows delivery of a multimedia presentation and provides different modes of interaction functions depending on the user needs.

For indoor exhibitions like museum kiosks, a combination of Web3D, VR and AR provides a very powerful interface that can be used successfully within any museum environment. Personalisation of the presentation: *provides museum visitors with a variety of options*; *offers accessibility to various groups of people*; *permits them to choose according to their preferences and desires*. For outdoor exhibitions, such as mobile guides, the presentation of map, VR map and AR map can give assistance to a wide range of users. The use of position and orientation information is essential for mobile presentations. Visitors can perform advanced searches taking into account the spatial location and personal interest using any of the presentation domains.

Acknowledgments

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References

[ADN08] ACCESS DEVELOPER NETWORK.: Available at: http://www.accessdevnet.com/, (last accessed: 27/07/2008.

[Arc*08] ARCO.: Augmented Representation of Cultural Objects.: Available at: http://www.arco-web.org/, Accessed at: 20/07/2008.

[BF04] BOWEN J.P. AND FILIPPINI-FANTONI S.: Personalization and the Web from a Museum Perspective, In *Museums and the Web 2004: Selected Papers*, Archives & Museum Informatics, David Bearman and Jennifer Trant (eds.), (2004), 63-78.

[BN04] BRUSILOVSKY P. AND NEJDL W.: Adaptive Hypermedia and Adaptive Web, In *Practical Handbook of Internet Computing*, M. Singh (Ed.), CRC Press, (2004).

[Cam*08] CAMINEO.: The digital guide for tourism, Available at: http://www.camineo.com/, Accessed at: 20/07/2008.

[DDA08] DISABILITY DISCRIMINATION ACT 2005.: Available at: http://www.direct.gov.uk/en/DisabledPeople/, (last accessed: 27/07/2008.

[Epo*08] EPOCH.: The European Research Network of Excellence in Open Cultural Heritage, Available at: http://www.epoch-net.org/, Accessed at: 20/07/2008.

[FD00] FALK J.H. AND DIERKING L.D.: The museum

experience, Walnut Creek, CA: Alta Mira Press, (2000).

[Gam01] GAMMON B.: Assessing Learning in Museum Environments: a Practical Guide for Museums Evaluators, London: Science Museum, (2001).

[KA04] KRUG K. AND ABDERHALDEN W.: Report on testing and validation, (2004).

[KFM*04] KEENOY K., DE FREITAS S., LEVENE M., ET AL.: Personalised Trails and Learner Profiling within E-Learning Environments, *Personalised and Collaborative Trails of Digital and Non-Digital Learning Objects D22 (4.1)*, (2004), 1-43.

[KT03] KELLY D. AND TEEVAN J.: Implicit Feedback for Inferring User Preference: A Bibliography, *SIGIR Forum 37*, 2, (2003), 18-28.

[LA*03] LUCRÉDIO D., ALMEIDA E.S., ET AL.: Orion – A Component Based Software Engineering Environment, *Journal of Object Technology, Special Issue: TOOLS USA 2003 3*, 4, (April 2004), 51-74.

[Lia07] LIAROKAPIS F.: An Augmented Reality Interface for Visualizing and Interacting with Virtual Content, *Virtual Reality 11*, 1, Springer, (March 2007), 23-43.

[Loc*08] LOCUS.: Development of Location-context Tools for UMTS Mobile Information Services, Available at: http://www.locus.org.uk/, Accessed at: 20/07/2008.

[MA97] MACDONALD G.F., ALSFORD S.: Towards the Meta Museum, *The Wired Museum: Emerging technology and changing paradigms*, Jones-Garmil K. (ed.), Washington DC: American Association of Museums, (1997).

[Mat97] MATEAS M.: An Oz-Centric Review of Interactive Drama and Believable Agents, *Technical report CMU-CS-97-156*, Computer Science Department, Carnegie Mellon University, (1997).

[MCS00] MOBASHER B., COOLEY R. AND SRIVASTAVA J.: Automatic Personalization Based on Web Usage Mining, *Communications of the ACM 43*, 8, (2000), 42-151.

[MM07] MOUNTAIN D. AND MACFARLANE A.: Geographic Information Retrieval in a Mobile Environment: Evaluating the Needs of Mobile Individuals, *Journal of Information Science 33*, 5, SAGE Publications, (October 2007).

[Mou05] MOUNTAIN D.: Exploring mobile trajectories: An investigation of individual spatial behaviour and geographic filters for information retrieval, *PhD Thesis*, Information Science, City University, (2005).

[Nic97] NICHOLS D.M.: Implicit Ratings and Filtering, In *Proc. of the 5th DELOS Workshop on Filtering and Collaborative Filtering*, Hungary, (1997), 31-36.

[Nie94] NIELSEN J.: Heuristic evaluation, In *Usability Inspection Methods*, Nielsen, J., and Mack, R.L. (Eds.), John Wiley & Sons, New York, NY, (1994).

[PC*00] PLETINCKX D., CALLEBAUT D., KILLEBREW A.E., SILBERMAN N.A.: Virtual-Reality Heritage Presentation at Ename, *IEEE Multimedia 7*, 2, IEEE Computer Society, (April-June 2000), 45-48.

[PP01] PARES N., PARES R.: Interaction-Driven Virtual Reality Application Design (A Particular Case: El Ball del Fanalet or Lightpools), *PRESENCE: Teleoperators and Virtual Environments 10*, 2, MIT Press, (March 2001), 236-245.

[RAS06] RUTLEDGE L., AROYO L. AND STASH N.: Determining User Interests about Museum Collections, In *Proc. of the 15th Int'l Conference on World Wide Web*, ACM Press, New York, (2006), 855-856.

[RS05] ROUSSOU M. AND SLATER M.: A Virtual Playground for the Study of the Role of Interactivity In Virtual Learning Environments, In *M. Slater (ed.) Presence 2005: The 8th Annual Int'l Workshop on Presence*, England, (September 2005), 245-254.

[SE*08] SYLAIOU S., ECONOMOU M., KAROULIS A. AND WHITE M. The evaluation of ARCO: a lesson in curatorial competence and intuition with new technology, *Computers in Entertainment 6*, 2, article 23, (2008).

[TSA03] TAN WEE HIN L., SUBRAMANIAM R., AGGARWAL A.K.: Virtual Science Centers: A New Genre of Learning in Web-based Promotion of Science Education, In *Proc. of the 36th Annual Hawaii Int'l Conference on System Sciences*, (Jan 2003), 156-166.

[VI*02] VLAHAKIS V., IOANNIDIS N., ET AL.: Archeoguide: An Augmented Reality Guide for Archaeological Sites, *Computer Graphics and Applications 22*, 5, IEEE Computer Society, (2002), 52-60.

[Wor97] WORDEN S.: Thinking Critically about Virtual Museums, In *Proc. of Museums and the Web*, Archives and Museum Informatics, (1997), 93-109.

[WP*07] WHITE M., PETRIDIS P., LIAROKAPIS F., PLECINCKX D.: Multimodal Mixed Reality Interfaces for Visualizing Digital Heritage. *International Journal of Architectural Computing, Special Issue on Cultural Heritage 5*, 2, Multi-Science Publishing Co Ltd, (June 2007), 322-337.