Tailoring the Adaptive Augmented Reality (A²R) Museum Visit: Identifying Cultural Heritage Professionals’ Motivations and Needs

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ABSTRACT
The paper presents the new concept of Adaptive Augmented Reality (A²R), employed within the context of the creation of an AR guide for the museum visit. The augmentations provided are not only visual but also acoustic, while the interest of the visitor is also monitored using physiological sensors, so that the multimedia content delivered to the visitor’s see-through AR display with which she can interact through gesture interaction can be adapted according to her engagement and interests. A theoretical framework is provided together with an overview of the system architecture. This contribution focuses on the interdisciplinary, collaborative and UC-informed methodology employed for the identification and elicitation of the motivations and needs of the Cultural Heritage professionals as to the potential of the A²R approach for the museum visit.

Keywords: Museum, Art, Cultural Heritage, Design, Interaction.

Index Terms: H.5.2 [User interfaces]: prototyping theory and methods, user-centered design; J.5 [Arts and Humanities]: Fine Arts; K3.1 [Computer and Education]

1 INTRODUCTION
AR applications have traditionally been related with the domains of architecture, medical and military training, computer assisted work and maintenance. However applications addressed to a wide-public were rare until recently. This explains why Cultural Heritage (CH) contexts -open by default to a wide public of different ages, social and educational backgrounds- provide a promising ground for experimentations with AR. From the 2001 ARCHEOGUIDE project, visually augmenting the archeological site in Olympia [1], AR seems to steadily gain its place as a technology providing alternative, rich and directly related to the site in Olympia [1], AR seems to steadily gain its place as a technology providing alternative, rich and directly related to the human senses contextualized information that may be used as an alternative channel and medium for museum interpretation, education and learning.

Moreover with the recent evolution that wants museums passing from a state of “being about something” to “being about someone”[2], the boom at the absolute number of existing museums and an attendance that has doubled from 1964 to 1984 [3], museums are not only competing with each other but also with other venues and attractions, while museum visitors become more and more demanding and interested in having a unique and tailored to their needs museum visiting experience. The evolving demands of museum visitors, the opening-up of museums to their public and the chase for an even more personalized museum visiting experience, set a new challenge and lead to a new generation of adaptive AR (A²R) guides that should be able to drive this personalization. Within this context our thesis is that the notion and essence of adaptation is the next step in the development of AR systems.

This contribution describes an approach for the requirements analysis and the design of such systems and introduces the European ARtSENSE project, targeting the creation of an Adaptive Augmented Reality (A²R) guide for the museum visit, for three different yet complementary Cultural Heritage Institutions in France, Spain and the UK. We focus on the design challenges that are inherent to a CH context where AR still qualifies as an emerging technology; engineers, researchers and software professionals are often unaware of the challenges of this particular domain-space, while Cultural Heritage professionals need familiarization with the potential of AR applications as an alternative interpretation medium.

The paper is organized as follows: we first provide a theoretical framework for the A²R approach. A²R monitors and augments the human perception not only through visual augmentations but also through a continuous monitoring and augmentation of the human auditory perception, all by taking under consideration the monitoring of the affective quality and impact of the physical and digital stimuli that may have an influence on perception, cognition and behavior. We illustrate this definition by providing the architecture of the A²R for the museum visit. We then visit the design challenges that are related both with the AR and the A²R approach and the methodology we used for gathering data for the elicitation of the motivations and needs of the CH professionals so as to solidly identify the system requirements, using an interdisciplinary, inclusive and User-Centered Design (UC) informed approach that places the CH professionals at the center of the design process. A comprehensive list of motivations and needs that can be covered by the AR and the A²R approach is provided, before summing up with conclusions and directions for future work.

2 FROM AR TO A²R: A THEORETICAL FRAMEWORK
AR has been praised for its potential to supplement the physical environment by overlaying digital information with which a user can interact. Rather than manipulating simultaneously a physical and a digital living and working environment, a concrete link is created between these two worlds, with the physical being augmented, enriched and supplemented by a digital canvas -seamlessly interwoven with the physical one- with which a user can interact. However, despite the fact that AR applications are becoming more and more widespread and popular, the notion and essence of adaptation is the next step in the development of AR systems.

This was one of the main reasons that in ISMAR 2009, Isabelle Pedersen [4], argued that “human users needed to be treated as centers, immersed in AR interfaces rather than as viewers, seeing interfaces or graphical overlays”. In providing arguments so that the human is restituted to the center of the design process, Pedersen used David Burrow’s phenomenology of sound and

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human thought [5] to propose three important early design ideas for AR applications: 1. Center the human participant. 2. Consider the idea of sound as much as the idea of sight. 3. Acknowledge that human participants move, think and exist simultaneously.

This theoretical framework puts in a nutshell the goals set up to be explored by the ARtSENSE project and the A²R approach; the project’s main motto is “See, hear, feel, sense, experience”, inspired by the sequence of the aesthetic experience as instantiated within the context of a cultural visit. The ARtSENSE visitor does not just see virtual overlays, menus and buttons. The visitor sees, hears and contemplates, interacts with both the virtual and the physical world in a seamless way and experiences feelings and emotions considered as playing an important role in the cognitive and affective impact that eventually constitutes the museum visiting experience. As in contrast with the existing trends in the AR scientific community more usually embracing and augmenting the visual and audio perception channels, A²R promises to cater for and provide visual and audio augmentations by monitoring, capturing and processing the human affective and cognitive knowledge about the impact of this blending of the physical and virtual worlds, an approach that has been identified as one of the least -if at all- explored [6] and one of the most intriguing and promising for the future, the potential as well as for one of the least -if at all- explored [6] and one of the most

2.1 Visual Monitoring and Augmentation

Burrows characterizes the individual, human being as a center with a tendency to treat everything else in the cosmos as peripheral to; he argues that a first field on which this center-periphery is projected is the physical space, through which the body moves, surveyed by the senses, with vision bearing the heaviest responsibility among them [5]. This is the important crossroad where it seems that the majority of AR applications, as observed by Pedersen [4], stand today: they design for humans considering them mainly as just viewers, seeing overlays, menus and buttons. This emphasis on visual augmentations can also be observed within the domain of CH related applications. Historically, in this domain the first AR applications started to appear within the context of outdoor visits, thus providing a tool for assisting visitors understanding how an archeological or historical site might have once looked like through visual augmentations, using a cumbersome equipment [2], [8], [9] or proposing fixed, AR installations that the visitor could manipulate on-site [10].

An important step in visual AR within a CH context coincided with the introduction of the first mobile multimedia guides for the museum visit, opening thus the way for an on-site delivery of not only audio but also multimedia interpretation material. Yet, the correlation of the signifier (the museum object exhibited) with the signified (as revealed by the multimedia interpretation material on the contemplated object) was not always an easy task. In order to assist the visitor in navigating both in the museum environment and the content of a mobile multimedia application, many geolocalisation, navigation and orientation solutions were put on the benchmark: declarative geolocalisation, Wi-Fi, RFID tags, Bluetooth and Infrared technologies [11]. The idea of assisting the visitor in visualizing context-aware information on selected artifacts and objects using AR techniques was just a matter of time. The first, though still rare, AR mobile museum applications appeared mainly on PDAs and UMPCs [12]. In 2009, the proliferation and spread in the use of iPhones and smart-phones and the upraising availability of relatively easy to use authoring tools- that had been since longtime preventing the implementation and rapid prototyping of AR applications- gave a tremendous rise in the creation of a new generation of AR-enabled mobile multimedia museum and CH guides available not only -as was the case earlier- on museum owned mobile devices but also on the visitors’ own devices: this is the case of the Phillyhistory.org project, overlaying historic photographs on the current urban landscape of Philadelphia [13], the ARtours project of the Stedelijk museum in Amsterdam [14], the morphing application MEandalthal of the Smithsonian Museum of National History or the Warhol application that –through a collaboration with Layar allows to see overlays in the cities where Andy Warhol lived and created. Despite the fact that this generation of light-weight mobile applications familiarized more the wide public with the use of AR within a CH context without some of the constraints imposed by the first generation of wearable AR systems for the CH visit, the small interaction surface still renders always apparent the boundaries between the real and the virtual preventing thus a total immersion of the museum visitor and a seamless interweaving of the real and the virtual environment, which is one of the main promises of AR.

One of the main novelties of the ARtSENSE project with regards to the visual augmentation of CH contexts is the use of a light-weight, optical see-through, AR display that can capture the eye-movements, the gaze and the hand gestures of the visitor. The eye-tracking can be used to trigger content while through the gesture interaction the visitor will be able to interact both with the digital and the physical environment in an intuitive way (an interaction example with the AR scene is presented in Figure 3D).

2.2 Acoustic Monitoring and Augmentation

The second component of the A²R approach that the ARtSENSE project is featuring is the audio monitoring of the environment in which the museum visit takes place as well as the adaptation of the audio augmentations that are delivered through the ARtSENSE system. Pedersen expresses this in her 2nd guideline, “Consider the idea of sound as much as the idea of sight”, arguing that “sight is a springboard for sound….things that one hears, free the imagination to create ones own sense of an authentic experience” [4]. Audio augmentations have a long history in museum pedagogy, education and interpretation media; the first predecessors of multimedia, then AR-enabled mobile museum guides have been the analogue, then digital audio guides [15]. However, the audio monitoring factor, which is the second important component of the A²R approach, is not just limited in the delivery of audio content to be combined with the augmented artifacts with which the visitor will be interacting. In an AR environment, the audio surroundings are monitored continuously so that the content is adapted accordingly; if a gallery section is too crowded, the visitor will be guided to another exhibition room, the volume will be adapted accordingly or the surrounding noise will be filtered out, providing an important service and guidance to the visitor. Another feature of ARtSENSE is the 3D audio spatialisation feature. As the system is aware of the position of the visitor, the artifacts can speak for themselves and address themselves to the visitor. Sound spatialisation and audio augmentation in CH contexts has been explored in the Ambient Wood project [16] as well as in the Musée des arts et métiers, in Paris, France, where audio spatialisation is used both as a navigation medium as well as a medium for the highlighting of the different sounds the machines once produced [17].

2.3 Affective Monitoring and Augmentation

The third and by far the most promising and least explored component of the A²R approach is the monitoring of the affective impact of the visual and audio augmentations and the interaction of a museum visitor with the physical and digital environment through the use of physiological sensors. This third component can be mapped with the 3rd guideline Pedersen emitted and
supported using Burrow’s phenomenology: “Acknowledge that human participants move, think and exist simultaneously.”

Museums are important informal learning environments. Lessons learned within this context could be also applied to other informal learning environments and urban settings. However there are still important gaps in our understanding of the interrelations among emotion, cognition and learning. In their influential work “Learning from Museums, Visitor Experiences and the Making of Meaning”, Falk and Dierking argue that the search for meaning or the need to make sense of an experience, as is often the case not only during a museum visit but in all activities of our everyday life, is an innate process [18]. We all make meaning through a constant process of relating past to present knowledge and experiences, in a way that is always relative and unique to the individual. This happens by continuously processing memories that -in case they are to become long term memories- need to pass through the hippocampus, an ancient, limbic area of the brain that is associated with human emotional processing. And for that to happen it seems that both an emotional as well as a physical context stamp need to be acquired. This is one of the main reasons for which they argue that learning occurs better under conditions of positive affect and suggest that the physical context (the museum surrounding, physical environment, the audio and visual augmentations) emotion and learning are highly interrelated. Negative affect on the other side have proved to be quite unsuccessful with regards to cognitive impact.

What needs to be underlined here is that the importance of affect and emotion is more and more recognized as a key issue in the successful design of products and interfaces and thus at the perceived usability and utility of a system [19] or product [20]. Under these perspectives being able to monitor the interest and the engagement of a museum visitor throughout an augmented museum guided visit can provide an important feedback about the personalization, adaptation and delivery of interpretation and learning materials that best fit not just predefined visitor profiles [21], [22] but the unique aesthetic experience a visitor is immersed in during a cultural visit. Thus, physiological computing, the third component of the A’R approach has a tremendous long-term potential not only for the personalization and adaptation of the museum visit but for a better understanding of the complex mechanisms that associate emotions, memory and learning.

3 THE ADAPTIVE AR MUSEUM VISIT: SYSTEM ARCHITECTURE

3.1 Architecture

In terms of software architecture, the main technological challenge is to develop an adaptive AR system that will be able to adapt the AR content to the current behaviour/preferences of a visitor, in order to provide a highly personalized, AR-enhanced, museum visit. The adaptation process as introduced by the A’R approach is a challenging one, including decisions about when to adapt the content, what kind of AR content to provide and how to present the content on the AR display. Note that the challenge lies in the complexity of the mentioned decisions since: a. these decisions are very interdependent (e.g. the “how” is influenced by the “when” and “what”) and b. the way these decisions are to be taken by the system are the responsibility of different types of project stakeholders (AR professionals, museum professionals, psychologists) that need to collaborate, communicate and share the same vocabulary, making thus necessary an all-inclusive and highly collaborative design process.

The system, which has been developed to realize the approach described in this paper, consists of several components that are efficiently combined in order to enable real-time adaptation of the information provided to a museum visitor based on the visitor’s current interest. Figure 1 illustrates the basic ARtSENSE architecture and the responsibilities for each of the decisions related to the adaptation process.

Figure 1: System Architecture and Collaborative Design

On the top of the schema are the sensors including the visual sensors (integrated in the AR glasses), the acoustic sensors and the biosensors. Sensor adapters connect to the sensor hardware, collect the sensor data and translate it into meaningful sensor events to be processed by the Interpretation module that is in fact a CEP (Complex Event Processing) engine. The CEP detects the situations of interests based on predefined patterns and real-time sensor data (i.e. a specific combination of the audio, visual and biosensing data). The detection (or lack) of interest will trigger the adaptation process (cf. WHEN in Figure 1, the responsible stakeholders are the project team psychologists who should define the patterns of behavior that indicate a change in visitor’s level of interest), based on the patterns that detect that the visitor has expressed an interest (low or high) in the presented part of the artwork. The Recommendation module consults the Metadata repository in order to select the best possible AR content to be used for the adaptation (cf. WHAT in Figure 1, the responsible project stakeholders are the museum professionals who know which content should be adapted in the case of change in the visitor’s interest while looking at an artwork/artefact). Finally, the Executor decides what is the best way to display the selected content, based on the visitor context (cf. HOW in the Figure 1, the responsible stakeholders are the AR experts who should define the best possible format of presenting/adapting the audio, video, text content to be delivered). This information is provided to the visitor, equipped with the optical see-through glasses and an audio headset as AR content. A Metadata annotation tool is used for supporting the process of creating AR metadata required for the A’R approach. All components communicate through an Event Bus by publishing and/or subscribing to events. In the following subsection we introduce the hardware including sensors and AR glasses that are used in this approach.

3.2 Visual sensors and AR glasses

To visualize the provided AR content special eyeglasses are used in our approach. The glasses have a novel optical see-through display which is capable of projecting information in the visitor’s field of view, as a virtual overlay. Additionally the glasses have the ability to track the eye movements. This gaze information can be used to index the direction of interest for the visitor. To be able to calculate the visitors gaze on an actual watched exhibit, an additional scene camera is used which is attached to the
eyesglass. The scene camera can track objects in the field of view of the visitor and gives the possibility to assign the gaze point of the visitor on the real exhibit.

3.3 Acoustic sensors

Background noises can be common in the museum environment: people talking, mobiles ringing, crowd, school groups etc. These sounds can affect and disturb the visitor. Therefore, to determine the level of attention towards an artwork and possible environmental disturbances, it is important to know what is happening in her acoustic proximity. To do so, the acoustic events and background noises are captured in real-time using a set of omni-directional electret condenser microphones and a multichannel audio data acquisition unit worn by the visitor. The digitalized signals are transferred in real time to the processing unit, which is in charge of applying the signal algorithms. These algorithms are divided in three stages. The first one consists of detecting the presence of any possible acoustic event that has occurred over the noise level. When a sound source is detected, the second stage extracts more information about the event and determines the level of disturbance. Finally, the third stage determines if the visitor has turned towards the acoustic event or not.

3.4 Biosensors

Biosensors are used for performing physiological monitoring, i.e. using sensors to read, store, process and interpret physiological data from organic beings, including biofeedback signals associated with heart, brain and other organ activity [23]. In our case physiological data retrieved from the body can be used for determining the user’s interest (and more importantly the changes in the user’s interest) for a particular artwork and part of the artwork. We have focused on following measures: a. heartbeat activity, b. skin conductance and c. brainwave activity. There are two very important challenges, namely how to interpret biosignals in a complex environment where several types of sensing will interfere (e.g. audio and visual, as well as user’s movement) and how to build a precise and robust classifier which can define the user’s interest from collected biosignals. Several field and lab tests have been performed in order to cope with these challenges.

4 Design challenges

In the previous section we visited the system architecture illustrating the A’R approach for a personalized museum visit. This section highlights the design challenges that were taken under consideration in order to select a methodology for gathering data so as to proceed with the system requirements analysis. It also briefly introduces the three European CH institutions that provide three unique and complementary use cases that can shed light on the benefits of an adaptive, augmented museum visit. As already mentioned in the introduction, AR technologies qualify as very promising but still emerging technologies within a CH context [24]. As pointed out in the AR literature, emerging technologies are very often characterized by inedited design challenges: they do not boast established design guidelines, neither specific nor standardized platforms; as innovation is upcoming and in search of potential applications, and corresponding technological concepts are still yet far from being the norm, end-users are rarely implicated in the design process. Even when this is the case, end-users might find it hard to know what to expect from the technology, especially when the latter is still evolving and has not yet reached a full potential [25]. An additional view, quite close to the CH domain, comes from the world of the collaboration for the design of interactive experiences among AR professionals and artists [26]. It has been noted that in such cases the artist has to identify the technology, appreciate its role, understand how it works, apply the technology concept in the design phase, then develop and create what has been designed while, on the other hand, the collaborating engineers have to accept going through a relative process, identifying, appreciating and understanding the role of their enhancements or technical interventions and their smooth and seamless integration in an always unique in character work of art.

The procedure that needs to be followed in the case of a close collaboration among researchers, engineers and museum and CH professionals is exactly the same: the CH professionals need to appreciate and work on the potential of the technology, understand how it works, apply the potential of the technology to the design phase, then develop, create but also test and evaluate the learning scenarios and the interpretation material they will be delivering through the AR guide. However, when designing AR applications as active assistants for museum visitors and the museum visit, an additional, important human factor has also to be taken under consideration, as in this case we can distinguish two different types of end-users: 1. the museum professionals that need to master the fundamentals of the technology and authoring tools to be used to tailor the AR scenarios. 2. the museum visitors that are eventually the main target group and the ultimate judge of the museum visiting experience targeted. To the above design challenges, one has to add the new notion and concept of the A’R approach.

4.1 Project background

ARTSENSE is a three-year research project grouping ten partners coming from six European countries, which can further be divided in five technology research partners (Complex Event Processing, AR visualization, Cognitive Psychology and Physiological Computing, Acoustics, Interpretative use of ICT technologies in Cultural Heritage), two industrial partners and three museum partners. The choice of inviting and including not just one but three CH partners, was a conscious one and motivated by the hypothesis that the deployment of an adaptive AR guide in three complementary types of museums could further push our understanding of the potential of the A’R approach, encourage the synergy among CH professionals and provide a more extensive coverage of the potential of AR and the A’R approach as an interpretation medium for the museum visit. More in particular, the three participating museums are:

4.1.1 MNAD: Museo Nacional de Artes Decorativas

The first museum partner is the Museo Nacional de Artes Decorativas, i.e. the Spanish National Museum of Decorative Arts, located in Madrid, Spain. The MNAD was one of the first European Museums of Decorative Arts and was established in 1912. Its collections are comprised of 70,000 items from Spain and abroad, featuring exhibits covering different typologies of Decorative Arts, like ceramics, textiles, glass and metalwork including Design. The permanent exhibition features approximately 3,000 exhibits while the museum receives approximately 30,000 visitors per year. Within the framework of the project but also following the typology of different types of museums [27], the MNAD can be considered as representative of Decorative Arts, History of Art and Archeology museums.

4.1.2 MAM: Le Musée des Arts et Métiers

The second museum partner is the Musée des arts et métiers, i.e. the French National Museum of the History of Science and Technology, located in Paris, France. The museum was established in 1794, shortly after the French revolution. Its collections have always –particularly during its early years- been linked with the technical, scientific and engineering training...
provided by the Conservatoire National des Arts et Métiers. The museum collections thus had always a strong educational character while the museum is always functioning under the auspices of the French Ministry of Higher Education. Its collections comprise 46,000 objects, 20,000 photographs and 15,000 technical drawings, while approximately 4,000 objects are displayed in the permanent exhibition at a surface of 6,000 square meters. The MAM collections are characteristic of the many challenges that are related with the public understanding of science and technology [28] that are also met in many other European History of Science and Technology museums.

4.1.3 FACT: Foundation for Art and Creative Technologies
Finally, the third Cultural Heritage institution participating in the project is the Foundation for Art and Creative Technology, located in Liverpool, UK. FACT is a multidimensional exhibition space that was funded in 1990 and can be considered as the less “traditional” CH institution participating in the project. FACT is one of the UK’s leading media arts organization, promoting new forms of artistic and social interaction between communities and individuals. FACT receives an average of 350,000 visits per year by encouraging the public to participation and engagement through activities targeting visitors of different ages and backgrounds. One of the main design challenges is that FACT has no permanent artifacts or exhibitions but functions with rolling programming of temporary exhibitions while also commissioning original artistic works with a particular emphasis on the use of New Media and Creative Technologies. FACT is representative of contemporary artistic creation centers, galleries and exhibitions showcasing the interrelations among Art, Artists, Technology and New Media [29].

4.2 Creating the 3rd space
Despite the remarkable originality of already existing AR applications for CH, it seems that even specialists can sometime face difficulties in expressing motivations and research hypotheses going further than phrases like “AR has been identified as an exciting new technology” [30]; especially if one takes under consideration that advantages and disadvantages of the AR approach have to be compared and informed by other advances in the use of ICT technologies in the museum environment. In the case of the ARtSENSE project, the inedited character of the A’R approach set additional design challenges for the project team.

In the design and conception of interactive systems, researchers and practitioners have been arguing that in order to arrive to the design of hybrid experiences that take place neither in the software professional space nor in the “workers” space but in an in-between region, defined as a third space, Participatory Design (PD) methods, techniques and practices may be of great assistance, provoking evolving combinations of attributes of each one of the bordering spaces, where the assumptions of both categories of stakeholders are open to questions [31]. According to Sanders the borderline that differentiates User-Centered (UC) from PD is the passing from “designing for” (where the researcher argues on behalf of the end-users) to “designing with” [32].

With this philosophy and for the first design iteration of the ARtSENSE project the CH professionals were identified as the “workers” and the first important group of end users who would actively participate in the design phase of the adaptive AR museum experience. In order to incorporate all of their know-how in the system requirements analysis as well as the design phase and the designation of the interactive features of the A2R museum guide, we opted for an all-inclusive, interdisciplinary and UC-informed approach. Ethnographic fieldwork as applied both in interaction design [33, 34], museum and visitor studies [35, 36] and the intersection of these two both domains [37], [38] also nurtured the data gathering prior to the system requirements analysis. The main issue that had to be tackled down during the first design iteration was how CH professionals perceive the potential of AR for CH, what is the added value of both AR and A2R, and in which way the adaptive character of this alternative interpretation medium can be fully exploited within the context of a CH visit.

4.3 Data gathering for system requirements analysis
In order to liberate the imagination and creativity of the CH experts it was important to work closely with them so as to answer some not always obvious questions such as: What is the look and feel of a see-through AR display? Why can AR provide an interesting alternative for the museum visit? How can we exploit and push to the limits the adaptive character of the ARtSENSE system for the benefit of both the visitors and the museum professionals? Which are the possible scenarios that can be developed?

Moreover, the system should respect the unique nature and particularity of the exhibitions and collections of all three participating CH institutions as well as their educational policies and strategies. Finally it was important to cater for an iterative design process that would later on open-up to the public targeted by the ARtSENSE project consortium: the museum visitors. Three main design iterations were designated: the 1st one would use all the creative power and collective intelligence of technical partners and CH professionals, the 2nd one would introduce the museum public while a 3rd variation (occurring in parallel with the 1st and 2nd iteration) would additionally introduce and invite one or more contemporary artists working with New Media to collaborate with the project team.

During the very first stages of the design process, an ethnographic approach was adopted in order to better comprehend the particularities of the domain-space, the museum, as well as the particularities of the museum visiting experience in all three CH sites, so as to gather data and initiate the enunciation of some stable and well grounded requirements. More in particular, the short ethnographic studies that were carried out consisted of:

- On-site, inobtrusive observations of museum visits in two out of the three CH institutions in the time span of a week (MNAD: two days, MAM: five days). Field-notes were taken while an emphasis was given on the way visitors used or looked for available, on-site interpretation material (text panels, audio guides, multimedia kiosks, etc). These observations assisted in better comprehending the types of interpretation media available on-site, the way visitors use them as well as the ways AR could assist and complement existing interpretation media for isolated visitors, consisting mainly of text panels (MAM and MNAD) and digital audio guides (MAM).

- Participatory observations of guided visits for different types of visitors (adults, children, school groups and families). Field-notes and -whenever possible- photographs were taken. This activity assisted in better understanding the types of narratives that are revealed through human guides in the museum exhibitions. For example, one of the most interesting findings in the case of the MNAD was that storytelling in the form of tales, as well as in the form of songs and music, are very much used and popular among children and their families. In the case of MAM, it was observed that many educational activities proposed to schools take the form of workshops, encouraging the children to observe specific details and aspects of an exhibit.

- Inobtrusive observations of creative workshops mainly addressed to children (MNAD and MAM). This activity helped the team to identify to which extent games and other education
activities are possible to inspire mini-games or interactive features in an A’R guide.

In parallel with these short ethnographic studies, questionnaires, interviews, brainstorming sessions and creative, on-site workshops trying out several of the components of the A’R system also occurred for the identification of needs and the establishment of domain-specific requirements. More in particular:

1. Informal and semi-structured interviews were conducted with all museum professionals. The goal was to understand the working practices followed, to define the work-chain that will be followed in each museum for the content production phase and the organization of each museum team. For example it was important to understand whether the teams implicated include professionals of the documentation department, the communication department or the educational department as the creative workforce and power of a museum professional working on New Media might be different that the profile of a museum professional working on Social Media or ICT and Documentation policies.

- Introducing the use of the A’R in the museum environment: The first step of utmost importance was to bring in contact the museum professionals with different types of AR see-through displays so as to enable them in obtaining the soonest possible a first-person experience on the look and feel of an AR environment in terms of visual augmentation. These tests were carried out in the MAM but also in a lab environment with the participation of all museum professionals and technical project stakeholders (Figure 2A and 2B). Gesture interaction experiments (Figure 2C and 2D) were also carried so as to start brainstorming around the ways humans can interact with the museum environment in a natural and intuitive way, once familiar interaction platforms disappear (e.g. mobile museum multimedia guides or audio guides). Experiments with initial audio spatialisation scenarios were also conducted in one of the use cases (MNAD) while in FACT, an open to the public demonstration delivering multimedia interpretation material with real-time biosensor monitoring occurred. These experiences also familiarized CH professionals with some technical constraints and challenges when using AR displays, as we will see in section 5.2.

- Brainstorming sessions: Following the demonstration of the AR equipment but also throughout regular intervals several brainstorming sessions occurred among all CH professionals (MAM, MNAD, FACT) on selected topics like gesture interaction, visual augmentation, acoustic augmentation.

- Immersion of the technical partners in the sensitive museum ecology: All technological partners assisted to specifically conceived guided visits in all three sites. The goal was a full immersion of the technical partners to the particularities of the sensitive museum ecology, while a collaborative exercise consisted of trying to analyze how a human guide interacted with the dynamics of the group and adapted the “content” to be delivered accordingly (MAM).

Finally, and once the selection of the first artifacts occurred (see section 6), a demanding exercise asked from the museum professionals to create pairs with the collocated technical partners so as to work on some first scenarios for the A’R museum visit. Thus, the MNAD worked with the acoustic processing team, the FACT with the physiological computing team and the MAM with the Museums and ICT technologies research team. The hypothesis was that the scenarios would present common features but also features that would be worked in more depth due to the specialty of each collaborating research partner (acoustics, physiological computing, ICT and the museum visiting experience). These scenarios took two forms: 1. Free-text narratives of an A’R museum visit. 2. Sketches and activity diagrams. 3. Flow-charts of possible themes and interrelations of content-chunks to be revealed.

![Figure 2A, B, C and D: AR displays and gesture interaction tests](image-url)

### 5 Identifying Motivations and Needs

The previous section explored the methodology followed to tailor the A’R museum guide to the aspirations and needs of the museum professionals but most importantly to bridge the gap in the understanding of the particularities of both the key-technology features of the A’R approach and the particularities of the museum ecology. This section presents how our design methodology and the data gathered shaped the enunciation of the main needs, motivations and challenges as identified and expressed by the CH professionals.

#### 5.1 MNAD: Museo Nacional de Artes Decorativas

The main motivations and needs gathered for the MNAD by the museum CH professionals were specific to the museum and its collections. However, as already pointed out the needs identified can be generalized to other history of art, archeology and history museums. In addition, as it will be demonstrated further on, many of these motivations proved to be valid for the MAM and FACT use cases. More in particular:

1. An AR approach gives the possibility to contemplate and observe museum artifacts for multiple points of view, something that due to space-constraints is not always possible on site.

2. Due to conservation reasons, many exhibits are exhibited in low light, preventing thus the visitor from having the possibility to view in an acceptable way all depicted details. In this case, the augmentations can assist the visitor in better observing difficult to observe otherwise details.

3. The MNAD possesses a collection rich in furniture. Artefacts of this kind have often hidden or closed compartments that can not be manipulated by the public. An AR system could assist the visitors in virtually manipulating these compartments, all by triggering curiosity and enhancing interactivity both with the artefact and the system.

4. Contextualisation of the pieces: the majority of museum artefacts are exhibited out of their initial context. Imagine for example a ceramic vase, discovered together with other artefacts, during an excavation. AR can assist in reconstructing, on site, the original context.

5. Glass showcases impose a certain barrier between the museum visitor and exhibited museum objects. A 3D view of these objects can be possible through the use of AR.
6. The comparison of a museum artefact with an object belonging to another museum or collection is something very common in art education. The use of an AR system could help visualize these twin pieces, often enough called “parallels”, among art historians even if –as is very often the case- they are not collocated. This is something that also holds true for other types of museums such as archaeology, ethnology, natural history museums as well as historical museums and parks.

Further on, some first, important motivations were also identified as to the A\R approach. More specifically:

7. The adapted content, suited not just to predefined visitors’ profiles but based on a continuous monitoring of the reaction of a visitor towards the exhibition and the content delivered through the A\R guide can make the visit more exciting and rewarding thus promoting intrinsic and self-motivated learning. For example, if excitement is detected, more information is provided about a specific detail. If boredom or fatigue is detected, the system can propose a change in the content, based on the logging of the narrative that has so far been provided and the reactions of the visitor to the already delivered content.

8. Through the use of the eye-tracking (visual sensing), the system does not only recognize predefined patterns but also monitors the gaze tracking of the visitor. This provides a tremendous tool that allows the museum professionals to know which are the artifact details a visitor is interested in, especially when combined with the use of physiological sensors.

9. The monitoring of the interest and engagement of the visitors, allows to follow the changes of attitude or feelings of the museum visitors during a museum visit, so as to better know how to organize an exhibition or the interpretation material (traditional or multimedia) that is being delivered.

10. Through the same mechanism, the system has also the potential of providing important information about each exhibit’s attractive power.

5.2 MAM: Le Musée des Arts et Métiers

All of the above motivations proved to hold true for the MAM museum. However, History of Science and Technology museum collections, particularly in Europe (and as in contrast with the more interactive, hands-on collections that originated in the United States) present some additional challenges due to the nature of the artifacts they are presenting and the inherent difficulties that are related with the scientific principles that are presented. Therefore, some important motivations and needs specific to Science and Technology museums that were identified were:

11. What scientific principles the object/scientist addresses that can be developed by the device through Augmented Reality? What are the technical aspects of the object that can be modeled, presented and explained in AR?

12. Is it possible to restore and render accessible to the visitors aspects of the intangible scientific cultural heritage, e.g. the sounds that once the industrial machines produced? The possibility of proposing a guided tour based on navigation and orientation in the museum using 3D spatialisation and enhanced audio features is something that can be rendered possible by the audio sensing and augmentation component of the A\R approach (audio sensing).

Some of the motivations identified by the MNAD professionals were also expressed in a more appropriate –for a History of Science and Technology- way. For example regarding Motivation 4, the museum professionals noted: “What is the historical context (including history of science) surrounding the exhibit? What is the sociological context that can be recreated under which the object falls? Was the innovation induced by the artifact at the origin of a significant sociological change?”

In addition, and as a result of the tests conducted on-site with several of the system components, particularly the AR displays, the MAM museum team members identified some technical challenges and constraints that should be taken under consideration for the selection of the scientific artifact to be augmented. Though for the AR community these observations might seem quite common, it is important to stress out the fact that they were detected, understood and reported by CH professionals with only a basic knowledge on AR systems and related technologies:

13. Poor lightening conditions may render the image recognition and processing more difficult.

14. The 3D nature of several technical and scientific instruments exhibited in the museum can be very complicated and challenging.

15. If lightening conditions are harsh, the installation of markers is not something possible for all exhibited objects due to preservation reasons. Another important guideline emitted by the museum professionals was that:

16. In order to provide a more meaningful and rewarding experience for the visitor, the museum team should opt for an object that can be viewed –both for aesthetic and technical reasons- from a variety of distances by the visitors that the system should be able to support robustly, with no risk of frustrating the visitor.

As to the potential of the A\R museum visit, some of the main benefits identified were:

17. For the MAM CH professionals “the more the visitor will live the visit, the more the souvenirs will be strong. Trigger the visitors’ imagination and encouraging active involvement in the digital narratives are essential keys. The work of immersion in the content is cognitive and sensory, particularly visual and acoustic”. The biosensing component has a great potential towards revealing positive and negative emotions that are generated, through the delivery of the multimedia content, in real time.

18. “The system’s adaptability to the visitor is essential. The dynamic and straightforward adaptation to the visitors’ profile allows smooth progressive learning preventing thus feelings of frustration and intimidation.” For example, if an explanation of a complex physical phenomenon is too difficult and the visitor is frustrated, additional, more comprehensible explanations could be provided by the system.

19. “The adaptation will be optimal if all the technical parameters of behavioral, psychophysiological and acoustic analysis are accurate and reliable. Caution however is needed to offer a relatively simple, transparent, lightweight and discrete equipment to avoid reluctance and non-acceptability of the system by the visitors.”

20. “The more the proposed device is original and innovative and stands out from any other IT based interpretation medium, the more visitors will be marked by the different discovery of the museum and the more the project will fulfill its potential.”

5.3 FACT: Foundation for Art and Creative Technology

The particularity of FACT is the non-existence of a permanent exhibition space as in contrast with more “traditional” museums and CH centers. This constituted a challenge that was resolved through the innovative idea of augmenting the FACT building itself, challenging the team to find ways through which A\R can be used to augment buildings, and social and public spaces: FACT in this sense constitutes a social and public space that attracts thousands of visitors in an annual basis. Some key-questions therefore were:
21. “How can we augment the experience of a visitor in relation to a building and the environment in which an artifact sits rather than the individual artifact itself?”

22. “Is it possible to make hidden elements (historical, social) visible and accessible so as to enhance the visitor experience?” (identical to motivation 4 covered also by the MNAD and the MAM).

23. “Is it possible to visualize the inner workings of a building, allowing access to “denied” areas reserved for the staff or the museum workers both from the interior and the exterior?”

With regards to the innovative character of the AR and given the extensive experience of the FACT team on working with new technologies, the motivations and ideas expressed were inspired, unexpected and original. As reported by the FACT project leader:

24. “FACT is looking for that elusive umami of visitor experience, the hard to define other that augments the event of visiting without intruding on the pleasure of passive engagement. The “FEEL” factor, -Fun-Engagement-Experience and Learning- without the sense of being confronted or challenged unwillingly. The biofeedback methods combined with the Augmented Content offer an opportunity for novel ways to engage the public and to gather useful information that will help the gallery improve and adapt the visitor experience according to individual needs” (note how this description complements the motivations 9, 17 and 18).

25. “FACT sees the possibilities around sharing and reporting of an individual experience in an exhibition or public environment a stimulating one. If the ARtSENSE project is able to create something dynamic happening between the public and private domains of visitor experience, and create a genuinely interactive as opposed to interpassive event for visitors, this is a step forward in the development of cultural heritage’s public engagement and an opportunity to be growing this emerging technology as a learning tool from the ground up.”

26. Further elucidating how the biosensing components might be creatively integrated in a unique visiting and learning experience, the FACT team proposed to explore whether “the user interaction with the technology, the individual journeys through the interface, can be captured and shared, and how this information can be disseminated live in engaging ways and reused to develop new approaches to exhibition design and augmentation”. Could it be possible not only to detect our emotions, towards a work of art or artifact but visualize them and share them with other co-visitors?

6 TOWARDS THE AR MUSEUM VISIT: SELECTING ARTIFACTS

Another activity of paramount importance, and one being constantly present throughout the full circle of activities described above was the selection of the first artifacts/objects to be included in the AR scenario for all three CH institutions. The artifacts should be emblematic for each CH institution and present a wealth of information to be revealed during the AR museum visit so as to push to a maximum the potential of the system, the underlying research hypotheses and the added value of the AR approach. After a first pre-selection, the artifacts on which the project team started working are:

6.1 MNAD: The 18th Century Valencian kitchen

The selection of a MNAD team was an 18th century tiled kitchen from a palace in Valencia (Figure 1B). The central scene depicts the preparation of an evening party with chocolate. The tiled kitchen was more used as a meeting place for the owners of the House and their friends than as an actual real kitchen. The kitchen is a unique assemble very rich both thematically and iconographically and can provide different types of narration for different visitor profiles (adaptation, personalization). In addition, because of the scenes depicted, thematic tours can be created related with themes such as everyday life, fashion, economy, society, religion (visual sensing through eye tracking and biosensing). In case interest is detected (visual sensors, biosensors) towards a depicted figure, detail and/or theme (through a multimedia or audio sequence), the system can guide the visitor (recommendation) to actual exhibits of the same period: for example, if the system detects that a visitor is interested by the jewellery of the house lady or some cooking recipients, she can later be guided to the gallery where real artifacts of this period are exhibited (metadata, recommendation).

Written sources of the same period (e.g. cooking recipes) can be easily associated and linked with the depicted content at a depth of detail that will be relevant with the detection of interest and engagement of the visitor. The kitchen can be viewed in 360° while the main figures are 2D and close to real-life figures, providing an excellent environment for trials using a markerless approach in the near future. The combination of the metadata tool and the 3D spatialisation module and audio annotation tool can provide different types of guidance: providing only text, in the case of an adult tour, or providing real-life dialogues (dramatization) among the persons depicted for children.

![Figure 3A, B, C and D: Initial artifact selection and system mock-up](image)

6.2 MAM: The Lavoisier Laboratory (1743-1794)

As with MNAD and FACT, after a first pre-selection the MAM provided a challenging artifact for both the AR and the AR approach. This selection does not include one, but several artifacts in the form of one exhibit: the laboratory of Antoine-Laurent de Lavoisier, considered by many as the father of modern chemistry. The laboratory presents the main equipment with which Lavoisier realized the experiment of the synthesis of water in 1785 (Figure 2A). A text panel and a short video are available on site, showing how some of the artifacts were used. But they are insufficient for an inexperienced visitor who has many difficulties in understanding what is being presented and how this equipment worked. An additional challenge of the Lavoisier laboratory –and other parts of the collection of the museum- is that there are many 3D objects (as in contrast with History of Art museums, where both 2D –e.g. paintings- and 3D objects can be viewed). As in MNAD, different themes can be revealed as this exhibit has a very strong historical, sociological, economical and political background. The content thus could be adapted so that visitors are provided with more or less information on these aspects and at different levels of details according to their particular interests (personalization, adaptation). Another particularity of the laboratory is the fact that the museum receives a lot of school...
groups. The audio sensing could thus either filter out the noise or even propose to the visitor another visiting trail (audio sensing, metadata, recommendation). An interesting scenario idea proposed by the museum team was to give to the visitors the possibility to connect all the equipment and realize themselves Lavoisier’s experiment (visual augmentation, gesture interaction): “Using ARtSENSE, the visitors can visualize the instruments, weight the gases, connect the gas meters to the balloon, create the spark and repeat Lavoisier’s experiment”.

6.3 FACT: The VIP Signature Pillar

As already mentioned in section 4.1.3, the particularity of FACT is the non-existence of a permanent exhibition space as in contrast with more “traditional” museums and CH centers. After a first pre-selection, the team decided to go on with a large-scale project that would explore the affinities in between architecture, urban spaces and AR and selected, as a first-case study, the VIP signature Pillar (Figure 3C). The Pillar is an architectural element of the FACT building, seen by the visitors as they enter FACT. Its particularity is that when VIP guests arrive in the building (film directors, artists, musicians) they are asked to sign it. The first signature appeared in 2007 by the film director Quentin Tarantino. The Pillar therefore provides a first artifact that through the ARtSENSE approach can provide the visitor with invisible information on the history of the building and some important events that marked its history, with the idea being that progressively other parts of the interior and the exterior of FACT can be augmented. Sketches, interviews, photos, movie extracts, music related with these VIP visitors can be therefore delivered to the visitors. As in the MNAD scenario, the continuous monitoring of the visual and physiological engagement of the visitor with the interpretation material delivered can lead to a more in-depth exploration of the narratives for each one of the VIP guests of the FACT Pillar.

7 Collective voices

One of the most important outcomes of this all-inclusive design methodology employed was the fact that very soon, the CH professionals decided on their own initiative to act as design mediators and facilitators and to invite critical audiences to the early design phase. The activities planned by the participating museums would implicate different types of professional groups and audiences. Thus the MNAD decided to implicate museum visitors for a better understanding of the types of information the museum professionals should prepare for delivery by the system by proposing guided visits of the Valencial Kitchen during eight sessions in a time-span of two months while the MAM decided to implicate in the design process museum employees representing all five museum divisions (pedagogy, collections, documentation, exhibitions, and communication department). Finally FACT decided to implicate an international artist collective, Manifest.AR (http://www.manifestar.info/) and ask them to collaborate with the consortium. The selection procedure of the retained proposals was also opened to all project-stakeholders. Manifest.AR and the synergy of the project consortium with them brings a new breath as to the varieties of ways through which A/R can alter and shape our everyday environments both in indoor (e.g. the museum) and outdoor operating and learning environments.

8 Conclusions and directions for future work

This contribution introduced the concept of A/R promising to provide a unique, augmented, museum visiting experience that will not only cater for the visual and audio augmentation of the interpretation material to be delivered, but will also monitor the physiological reactions of the museum visitor. In this way museum professionals are not only assisted in better adapting the interpretation material to be delivered; they are also provided with a tool for better understanding the complicated ways through which cognition and learning in informal learning environments - like museums and galleries - is experienced from an affective point of view, suspected by many to have a direct impact on human cognition.

The important design challenges related both with the AR aspect and the new notion of the A/R museum visit were visited together with a methodology for the elicitation of motivations and needs so as to proceed to a well grounded system requirements analysis. The architecture of the system was presented, while a comprehensive list of needs, motivations and aspirations as expressed by the CH professionals was populated. The majority of the motivations and needs identified were related with the most common features that one can expect from a usual AR museum guide. The A/R related motivations also generated a lot of collective knowledge and understanding as to how an A/R system could better serve museums and CH institutions but the inedited character of this approach certainly seems to indicate that there is still a great potential to be progressively explored.

However, one of the most important issues this contribution intended to illustrate was the important role the CH professionals undertook in evolving our understanding about AR and A/R as a new interpretation medium, as a result of an interdisciplinary, highly inclusive and UC-informed design approach. In addition, the first group of our end-users, the CH professionals, became the facilitators for the inclusion of other interested societal groups in the early design phases.

It might be disorientating however not to mention some important issues that are related with the life-circle of the project. Indeed, the active participation of CH practitioners at the definition of a cutting-edge technology mediated tool for the cultural visit might stretch the time needed for the process of the system requirements analysis as several intermediate steps and actions were necessary before arriving to solidly ground the first functional requirements, mock-ups and prototypes. However behind this very first impression, the active participation and implication of all project stakeholders guarantees a better reflection on the possible challenges of the A/R approach, by raising the investment, the inspiration and the creativity of all project stakeholders.

The second year of the project will feature tests, design and evaluation activities with museum visitors that will feed into the design of a 2nd prototype of the ARtSENSE system while new questions, linked with the notion of A/R will not cease to come to surface. What can we learn for the affective and emotional experience of a visitor during a contemplation of a work of art? Can the system assist in recording and better understanding this experience? Will we eventually start to have a better understanding of the paths that link cognition, emotion and learning? The above questions will be tackled down using the same design approach and philosophy by introducing the second most important group of end-users to be implicated in this iterative design process: the museum visitors for which the A/R museum visiting experience is being tailored collaboratively.

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