

# EXPLORING THE AFFECTIVE MUSEUM VISITING EXPERIENCE: ADAPTIVE AUGMENTED REALITY (A<sup>2</sup>R) AND CULTURAL HERITAGE

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**KEY WORDS:** museum visit, Augmented Reality, multimodal interaction, eye-tracking, acoustics, affective computing, personalisation

## ABSTRACT:

Providing engaging interpretation resources for museum and gallery visitors may have a great impact on the overall museum visiting experience all by assisting museums maintain long-term relationships with their public. This paper focuses on the ways through which AR can be employed in museum and gallery settings as an interpretation medium. It also introduces a new generation of multimedia guides for the museum visit inspired by the concept of Adaptive Augmented Reality (A<sup>2</sup>R). Adaptive Augmented Reality (A<sup>2</sup>R) provides visual and acoustic augmentations that come to supplement the artefact or site viewed by a museum or gallery visitor and monitors the cognitive and affective impact of all interactions of the museum visitor both with the physical and the digital environment. The ultimate goal is to make every museum visit unique, by tailoring an Augmented Reality visit with contents that are susceptible to increase the affective impact of the augmented museum visiting experience and hence encourage intrinsic and self-motivated learning.

## 1. INTRODUCTION

### 1.1 Augmented Reality in Cultural Heritage settings

During the last years, Augmented Reality (AR) applications are steadily gaining their place in Cultural Heritage contexts as an alternative interpretation medium for the museum visit. Museums, galleries as well as historical and archaeological sites can provide exciting environments for experimentations with AR applications for a public of different ages and backgrounds. Though the first AR display appeared in 1965 (Sutherland, 1965) it was only after 1993 and the appearance of an AR dedicated volume in the ACM Communications Magazine that the term AR started to be more widely used and well-known (Cohen, 1993).

The first AR applications for Cultural Heritage were implemented for important archaeological sites assisting the visitors visualising how an ancient site might once have looked like by using quite invasive and heavy Head Mounted Displays (HMD) that allowed to supplement one's perception of the real, physical, surrounding environment with virtual overlays with which a visitor could interact (Vlahakis et al., 2002). These first applications were certainly immersive but also bulky and cumbersome. In the following years, a limited number of mobile AR applications within a Cultural Heritage context started also to appear mainly using PDA's or Ultra Mobile Personal

Computers (Damala et al., 2008). From 2009 onwards the proliferation in the use of smartphones (iPhones and androids), the advances in storage and processing capacities and the integration of cameras and screens allowing the combination of the real with the virtual on mobile devices provided a fertile ground that encouraged the conception of a large number of mobile AR applications for museums and Cultural Heritage contexts. Thus, in 2010 and 2011 AR made its appearance in the influential "Horizon Museum Edition" report as a powerful, emerging technology for museum interpretation and learning that has the potential to provide to the visitors layered information about an object on a simple, non-invasive way in a discovery-like and location-driven manner (Johnson et al., 2011). Examples of successful and intuitive applications that often enough also assist museums to extend their exhibition spaces beyond their physical settings and into the city include the Andy Warhol application of the Andy Warhol museum in Pittsburgh, USA (<http://www.warhol.org/connect/mobile/>), the AR tours of the Stedelijk museum in Amsterdam (Schavemaker et al., 2011) or the Museum of London (<http://www.museumoflondon.org.uk/>) Street Museum application.

However, one needs to be aware that though mobile AR applications have made AR available and accessible to the large public, the small interaction surface of smartphones does not favour a total immersion of the visitor in an AR environment in

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which ideally there is no boundary among the real and the virtual. Moreover, the content and augmentations provided most usually adhere to predefined and static visitor profiles (e.g. adults, children, families) but are not tailored to provide a unique visiting experience according to unique impact different stimuli may provoke to an individual visitor during an “augmented” (traditionally or digitally) museum visit. Such static and predefined visitor profiles are certainly very useful for creating general nature narratives addressed to different ages, but fail to monitor and assess the impact of each single interaction a museum visitor may have with the museum environment, the artefacts and the multimedia content delivered once engaged in augmented museum visit. The European ARiSENSE project seeks to address the above challenges. ARiSENSE uses a novel optical see-through display with which a visitor can interact through natural gesture interaction and introduces the concept of Adaptive Augmented Reality (A<sup>2</sup>R): this is a space where the augments are not only visual but also acoustic while the monitoring of the affective impact of all the physical and digital stimuli is exploited so as to adapt the content to be delivered to the visitor accordingly. The project consortium regroups six research/academic and three Cultural Heritage partners: the Museo Nacional de Artes Decorativas, in Madrid, Spain (representative of challenges met in Art and Design museums), the Musée des Arts et Métiers, in Paris, France (representative of the challenges met in History of Science and Technology museums) and Foundation for Art and Creative Technology, Liverpool, UK (here the challenge lies in the fact that no permanent artefacts or objects exist but temporary rolling exhibitions investigating the interrelations among New Media Art and Emerging Technologies). Thus, A<sup>2</sup>R system is conceived and validated for three different yet complementary types of museums and Cultural Heritage institutions.

## 2. ADAPTIVE AUGMENTED REALITY (A<sup>2</sup>R)

### 2.1 A<sup>2</sup>R: A definition

AR applications are most usually associated with visual augmentations that sometimes tend to consider human beings merely as “viewers, seeing interfaces or graphical overlays” (Pedersen, 2009). The promise of A<sup>2</sup>R is to bring the human back to the centre of the design process by attributing an extreme importance not only to the notion of vision and sound, but also by continuously monitoring the visual, acoustic and affective context within which the experience takes place when using an immersive Augmented Reality application as the main vehicle for museum education and interpretation. Exploring the potential of emotion and affect for museum learning as well as better understanding the visual, acoustic and emotional engagement of a museum visitor has a great potential towards proposing a unique, personalised experience that will fit not just to static, predefined, visitor profiles but to each single visitor’s experience and the particularities of each museum visit.

### 2.2 Visual Augmented Reality Applications

Most current systems for AR are video see-through hand held devices like smart-phones. These devices become more and more powerful and cheaper and are already very well positioned in the mass market. Nowadays, there exist many software development kits exist that make easy to implement basic, mobile AR applications. Hand-held devices have been already used in AR projects in the cultural heritage domain as we saw in the introduction. Another approach, using projectors, has been

presented by Mistry and Maes (Mistry & Maes, 2009). The system, called Sixth Sense is based on a small projector-camera setup, which is worn by the user and allows projecting information onto different surfaces in front of the user and the interaction with the projected information. However, these devices and setups are limited in field of view and handling is laborious, which affects the impact of AR. Head-worn devices may solve this problem, but they are expensive and only few light weight devices are already on the market, e.g. Vuzix’s STAR 1200 ([http://vuzix.com/augmented-reality/products\\_star1200.html](http://vuzix.com/augmented-reality/products_star1200.html)) or in research, like, Nokia’s near-to-eye display (Järvenpää & Aaltonen, 2008) or Google glasses (<https://plus.google.com/+projectglass/posts>). A research project of Fraunhofer (<http://www.interactive-see-through-hmd.de>) recently started to sell evaluation kits of head mounted devices, which allow displaying information on an optical see-through display while simultaneously analysing the user’s gaze.

### 2.3 Visual Behaviour Analysis

Visual behaviour of a user may valuable information on his/her attention. With the availability of mobile eye trackers it gets possible to analyse visual attention of users in many situations, like in shopping centers, sport events or galleries and museums. In 2010 Milekic (Milekic, 2010) describes how eye tracking found its way into museums and presented different applications and benefits museums may achieve from eye tracking, like collecting data for museum studies, or enhancing knowledge dissemination via Web-based applications. More recently Bachta et al. (Bachta et al., 2012) evaluated the practical applications of eye tracking in museums using a fixed eye tracking setup. One of the most important findings was that a calibration is needed to estimate gaze direction accurately in a museum setup. Also Toyama et al. (Toyama et al., 2012) are evaluating the use of eye trackers in the museum context. Their research project Museum 2.0 enables users equipped with a Mobile Eye Tracker (MET) to get more information on mobile devices, based on their gaze. In 2013 Eghbal-Azar and Widlok (Eghbal-Azar & Widlok, 2013) presented potentials and limitations of MET in visitor studies, based on experiments in two museums. They found out that though MET data yields a lot of helpful information, it must be combined with other methods to gain new insights into individual experiences. Also, application of MET is laborious, due to technical limitations of state-of-the-art METs and due to the lack of software tools for comprehensive automatic analysis that could effectively treat all of the amount of data that needs to be analysed.

### 2.4 Acoustics – Audio Augmented Reality

Providing intuitive access to an increasing amount of information in everyday environments is a great challenge. AR systems address this issue mainly focusing on visual augmentations and enhancements. However, there exist surprisingly few attempts of utilising audio user interfaces in real life environments. In that sense, Audio Augmented Reality (AAR) systems provide a full framework to design and create spatial audio applications. This requires that the perception of natural environment has to be preserved as well as possible, unless some modification to it is desired. In (Rämö & Välimäki, 2012), the use of digital filters is proposed to realize the required equalization of the sound. In addition, the devices used are based on a headset with earphones feeding sound to the ear channels in combination with a set of microphones, as described

in (Tikander et al., 2008). In (Härmä et al., 2004), a framework is introduced for Mobile Augmented Reality Audio (MARA) while the design and evaluation of mobile and wearable appliances are also thoroughly considered. Other proposed applications of AAR, take advantage of the innate human capacity for 3D sound source localization and source separation to place at specific points acoustic virtual objects for visually impaired people (Ribeiro et al., 2012).

However, the novelty of ARtSENSE project regarding the field of Audio Augmented Reality is based on the idea that the perception of an artwork, does not only depend on the artwork and the user, but also on circumstances beyond his control. The specificities of the acoustic environment in which the perception of the artwork takes place may directly influence the visitor experience but also the perception of the artwork itself during the augmented museum visit. Therefore, the different acoustic events or noises present in the artwork's proximity as well as the visitor voices are of particular importance. Acoustic analysis of a given scenario including audio events and interactions has been recognized during the last years as a powerful source of information in different monitoring applications. In (Atrei et al., 2006), processing audio signals yields the detection of different human activities, such as shouting, talking, walking, and crying. In (Wu et al., 2009) and (Huang et al., 2010), monitoring the home environment and identifying acoustic events, like shouting, is considered as a mean for identifying situations where providing immediate assistance to elderly people is necessary.

Within the ARtSENSE project, a complete acoustic scene analysis is carried out using a set of microphones, in order to detect, identify and localize all types of sound events surrounding the artwork and the visitor. This information is then used to provide a more immersed experience adapted to the visitor by using personalized 3D sound effects which aim to improve the perception of audio contents by creating a given auditory impression to a listener depending on the level of interest or engagement/disengagement.

## 2.5 Physiological Monitoring and Affective Augmentation

As already mentioned, monitoring the physiological and affective reactions of a museum visitor during the augmented museum visiting experience is the third and maybe most intriguing component of the A<sup>2</sup>R concept.

Brain and body signals provide a wealth of information about the psychological state of the individual. Physiological signals, e.g. brainwave activity, can be monitored in both an autonomous and continuous manner using sensor technology. This data can be used to create and maintain a model of an individual's psychological state which can in turn be used to personalise an interactive system to an individual user. For example, physiological markers of workload and motivation to dynamically control a videogames level of difficulty have been used and exploited in order to maintain player motivation while avoiding under or over challenging the player (Fairclough and Gilleade, 2012). Systems which use physiological data as an input control are known as Physiological Computers (Fairclough, 2009).

The aim of the ARtSENSE system is to optimise the visiting experience in Cultural Heritage contexts using a combination of AR and adaptive software. A physiological computing approach is ideal for this task because it provides a continuous stream of

real-time information pertaining to their user's psychological state which can be used to inform decisions made by an adaptive system. For example, if the museum visitor's physiology indicated a positive emotion is experienced whenever a particular style of artwork is viewed, the system could dynamically create a museum tour based upon similar works that are likely to elicit a similar response.

Curating content to promote a positive emotional experience is just one of many types of adaptation that could be envisioned in a Cultural Heritage context. Viable adaptive strategies will vary according to the type of experience a museum curator wishes to provide their visitors given the works they are displaying. For instance, we know surprisingly little about interactive Cultural Heritage experiences intending to promote a positive emotional reaction. Therefore designing, implementing and creating interactive narratives and stories for a system that attempts to do so can prove to be a real challenge in terms of preparing and adapting multimedia content to be delivered to the museum visitors during an A<sup>2</sup>R museum visit.

## 3. A<sup>2</sup>R: ADAPTING THE MUSEUM VISIT

### 3.1 System Overview

As already explained, the main novelty of the system is related to the multimodal interaction between the visitor and the artwork, that enables better understanding of the visitor preferences, knowledge and the needs. This understanding will be used for more tailored suggestions related with important questions regarding the content adaptation for creating a memorable, individual and meaningful visitor experience (when to adapt the content? how to adapt the content? What kind of content to provide?). Attempting to This leads to a new type of AR systems that will be able to gather preferences from a user, combine those with her past behaviour and contextualize with available content in order adapt the presented content accordingly. In the nutshell of this process is the determination of the level of interest while the visitor is contemplating an artwork or museum artefact. To reach this goal, a system model has been proposed, where different inputs to the visitor and different outputs from the visitor exist within the same framework and are taken under consideration for the adaptation of the Adapted AR visit.

As it is shown in Figure 1, when the visitor is contemplating an artwork, the stimulus acts as an input to the visitor. Additional inputs that can influence the level of interest of the visitor are: the environment, e.g. sounds that can disturb the visitor, and multimedia content the digital, AR guide is providing, e.g. images, videos, animations, text, audio comments, sounds, 3D visualisations. The latter are provided through the AR see-through glasses, capable of projecting information in the visitor's field of view as a virtual overlay and acoustic recordings (audio commentaries and sound effects) through headphones. Therefore, the artwork, the environment and the AR content delivered to the visitor are all considered as input parameters for the visitor. Additionally, the system monitors several outputs of the visitor in order to determine the psychological state and more precisely the surrounding acoustic environment (sounds and noise that can disturb), the gaze (where the visitor is looking at and for how long), and finally the biosignals or physiological responses of the visitor (heart rate, breath rate, skin conductance level). The result of these modules will be combined to obtain the psychological state of the visitor and determine the level of interest with regards to

what the visitor is looking at, or listening to but also in order to determine when a visitor is disengaged.

The main technological challenge is related to the need for integrate different sensor technologies in real-time fashion in order to enable the detection of some specific situations based on the user's behaviour (that will be used as candidates for performing adaptations).

### 3.2 User Monitoring

Given the above A<sup>2</sup>R definition and the description of the main A<sup>2</sup>R system components, the main target and challenge within a Cultural Heritage context is to propose and immersive Augmented Reality guidance system, able to continuously monitor the experience of the museum visitor and adapt the AR content and narratives according to the engagement and interest manifested by the visitors as monitored and interpreted by all visual, acoustic and physiological sensors. In order to address this challenge ARtSENSE determines levels of interest, while the visitor is engaged in the museum visit: within ARtSENSE, engaged in the museum visit may mean engaged either in contemplating the physical scene (the artefact and the surrounding museum environment) or the augmented scene (the digital overlays that supplement the physical scene). Therefore, in order to be able to determine levels of interest, the ARtSENSE system model defines several inputs and outputs to and from the visitor, existing within the same framework that are taken under consideration for the A<sup>2</sup>R visit.

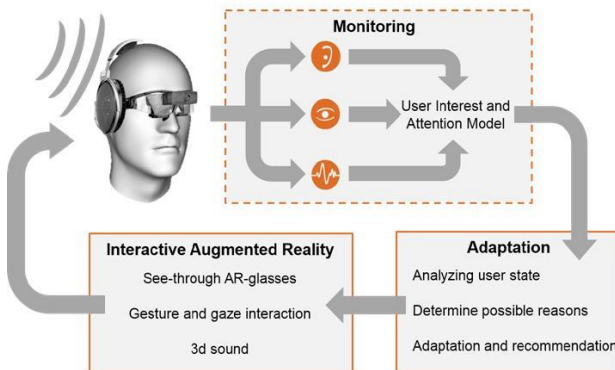


Figure 1: The adaptation circle in ARtSENSE

Figure 1 presents the adaptation circle that leads to the content delivery and adaptation. The first obvious stimulus, at the beginning of each museum visit with ARtSENSE is the physical scene, i.e. the visual stimulus on which the visitor will choose to concentrate. However and as the visit progresses, several additional inputs and events can influence the interest level of a visitor on the physical scene and the interactive, digital content that supplements the physical scene. Sounds coming from the surrounding environment, the types of multimedia content delivered (audio, video, text, 3D animations, sounds, 3D models), and their impact on an affective level (measured and monitored through the use of biosensors) are all inputs that need to be analyzed in real time so as to adapt the content to be delivered to the visitor in form of digital overlays and audio augmentations. The artwork, the environment as well as the content with which a visitor is interacting are considered as input parameters in ARtSENSE. In parallel however, several

outputs of the visitor are also used as parameters that assist in determining how the content should be adapted: the gaze of the visitor on the artwork (where is the visitor looking, at which order and for how long), the surrounding acoustic environment (sounds and noises that may indicate a disturbance) and finally the physiological responses of the visitor (heart rate, breath rate, skin conductance level). The inputs obtained from all these modules are combined to obtain the psychological / interest state of the visitor and define the interest, engagement or even disengagement level with regards to what a visitor is looking, hearing and interacting with during the A<sup>2</sup>R museum visit. In order to achieve this, ARtSENSE employs three different types of sensors: visual sensors in order to estimate user's focal attention, acoustic sensors, for measuring events in the environment and bio sensors, which yield information about the physiological state of the user.

### 3.3 Visual Sensors

Analysing visual behaviour of a visitor contains two parts, namely gaze estimation and gaze analysis. The first part can be further separated into eye-tracking and gaze estimation. Eye-tracking is dedicated to finding the users eyes, pupils, glints in the camera adjusted to the users. Gaze estimation translates the features found from the eye-tracking into the 3D-world, i.e. gaze or screen coordinates. The coordinates of the gaze may then be analysed over time. This yields fixations and scan patterns which may be used to estimate interest status of the user, e.g. when the user fixates on an object, he is interested in the object and may want more information about it.

As stated in Eghbal-Azar and Widlok (Eghbal-Azar & Widlok, 2013), current METs technology is somehow limited as that visual perception is only partially captured and general problems of electronic gadgets under adverse field conditions may often occur. However, most problematic is the user gaze analysis, especially in real time.

ARtSENSE is based on a new head mounted device (HMD) which is developed in a Fraunhofer project (<http://www.interactive-see-through-hmd.de>). This device allows displaying augmented content while simultaneously estimating the users' gaze. A drawback of this solution is the low resolution eye tracking camera. Therefore novel algorithms are developed which allow low resolution eye tracking under varying illumination and for a larger range of users. Moreover user pose estimation techniques are developed, which allow tracking the user's pose, i.e. position and orientation, in the museum, based on a camera mounted on the HMD pointing in direction of view of the user. Thus, combined with eye tracking, gaze calibration and 3D models of artworks in the museum, real time gaze analysis is possible. Some first experiments carried out using the Vuzix STAR 1200 showed the potential of the developed user tracking algorithms, but also demonstrated that within the A<sup>2</sup>R framework we have been developing in ARtSENSE, pose estimation is not accurate enough for user attention estimation since Vuzix glasses do not support eye tracking.

### 3.4 Audio Sensors

The acoustic environment and its influence on the attention that a visitor may pay to an artwork have been so far scarcely studied. As the acoustic events occurring in the proximity of the visitor can affect and disturb the visit, it is important to monitor

and understand what is happening around the visitor. For this reason, the acoustic monitoring of the environment in which the visitor is immersed pretends to detect the possible background noises (long-term or persistent sounds present in the scenario or visitor's proximity such as noise/murmuring of the crowd present in a room, constant air conditioning machines, etc.) and sound events (short-term acoustic events that can occasionally occur such as child crying, shouts, handy ringing, sneezes, sirens, etc.) that can drive away the user's attention. In both cases, the challenging aspects that influence the acquisition of such acoustic signals and their processing are numerous: e.g. the stationarity of the background noise, the acoustic characteristic of the room, the knowledge about the sound events to be detected and the existing Signal to Noise Ratio (SNR). For that purpose, ARtSENSE captures the acoustic events and background noise in real-time using a set of omni directional microphones and a sound card. The specific number of microphones and the placement layout is a matter of study and research to reach the best performance in a major number of situations. Furthermore, the specifications of the microphones and the audio acquisition unit must be as well adapted considering the system constraints. The data is acquired by using a multichannel audio data acquisition unit with the sampling frequency of 48 kHz, responsible of digitalizing and transferring the digitalized data to a processing unit having the required computational power to implement the real-time processing requirements. In this case, novel algorithms dealing with detection of unknown sound events in adverse noise conditions are implemented and extended (Moragues et al., 2011a). In a later stage, classification algorithms based on supervised learning are used and improved to extract more information about the event (Moragues et al., 2011b). The feature selection and extraction, as well as the classifier used play an important role and represent a great deal of research within this project. Similarly, the location of events in the visitor's environment and the detection of the rotation of his head towards it are crucial to understanding any behavior or change in the visitor's attention. For this reason, new localization algorithms and detection of head movement based on sound will be in constant evolution within ARtSENSE.

### 3.5 Physiological Sensors

The experience of a Cultural Heritage environment, regardless of whether it is a museum or gallery, is shaped by an exploratory behaviour driven by the interest and curiosity of the visitor. The ARtSENSE system proposes to explore and investigate psychophysiological measurements of interest in order to drive system adaptations, by taking under consideration three sub-components: 1. activation: how aroused someone is, 2. cognition: level of mental effort and 3. valence: level of positive or negative feeling towards an object. Activation is measured through changes in heart beat rate and skin conductance. Cognition is measured through changes in the ratio of beta to alpha wave brain activity at FPZ on the 10-20 system, an electrode placement scheme for electroencephalogram (EEG) electrodes. Valence is measured through changes in alpha wave activity between the left and right brain hemisphere between EEG electrode sites FPI and FP2. All three electrode sites are located on the forehead below the hair line. The development of a cognitive-emotional model of interest is intended to represent those psychological dimensions that contribute to memorable experience in a Cultural Heritage setting. These measures, pertaining to a visitor's interest are provided to the adaptive component of the

ARtSENSE as a series of LOW, HIGH states which can be used to drive a number of different adaptations depending on the curatorial requirements of the museum.

### 3.6 Interactive Augmented Reality

As stated in Section 3.2, a novel head mounted device is used in ARtSENSE. The optical see-through technique allows the user to see his/her surrounding environment at all time, while additional information may be added into his/her field of view. The system will provide the possibility to display text, images, videos, animations and 3D objects in different formats. These contents may be viewed filling out the display of the device or referenced to the artwork.

In order to interact with the ARtSENSE system and contents, different gaze and gesture based interaction techniques are evaluated. Gaze interaction may be used when reading text, e.g. text scrolls up, when the system has detected by gaze analysis, that the user has read a specific part of the text. Another gaze interaction scenario is exploring augmented content, e.g. large images where the user may zoom in and see different parts of the image in more detail just by looking at it. Gesture based interaction may be used for more implicit interaction, like pressing buttons or wiping through galleries. Using gestures for interaction implies two steps: First, the hand of the user must be recognized and, for dynamic gestures, tracked over time, second, a dictionary of gestures must be defined which can be used for interaction. The camera mounted on the HMD, which is used for user pose estimation, is also used for hand tracking. Novel algorithms are developed and evaluated in order to recognize hands with a single RGB camera also in adverse field conditions. Also a set of interactive gestures is defined, which is on the one hand, intuitive, comfortable and easy to remember for the user, but also recognizable with the used setup and developed algorithms for hand tracking (Figure 2).



Figure 2: Different styles of natural gesture interaction in the 18<sup>th</sup> century Valencian ante-kitchen, Museo Nacional de Artes Decorativas, Madrid, Spain

The audio output plays an important role for the visitor since it is necessary to deliver the audio information about the artwork in the most appropriate and adapted way. This implies that as we hear sound in three dimensions, the reproduction of spatial aspects of audio is essential to digitally create, recreate or enhance an artwork perception. Within this framework, in the ARtSENSE project the audio information/contents are provided to the visitor through stereo headphones while different real-time audio processing techniques are implemented to reach a better audio augmentation of the artwork. In that sense, different reverberation and holophony techniques (Habets, 2010; Rakerd

& Hartmann, 2010) are being used with the objective of achieving satisfactory results in terms of immersion and spatialization results. The objective of these effects is that, independently of the position, the visitor has the feeling that the artwork speaks directly to him in a specific environment. In this case, it is necessary to know the type of room, as well as the position of the visitor and the acoustic source with respect to the artwork.

However, the novelty of this project is not focused on the development of these techniques but on the study on how these audio effects can be used and adapted depending on different conditions such as the acoustic environment (as described in section 3.3), user interest, visitor position, user profile, etc. A robust audio player has been developed to support the variety of audio controls and audio effects required to achieve this aim. Furthermore, the integration and communication of the audio player with other components of the system is of particular importance since the synchronization with the image and the text provided is crucial for the correct presentation of the available artwork contents.

### 3.7 The Metadata and the Audio Annotation Tool

One of the main challenges in realizing this kind of systems is to enable a smoothly deployment in the real environments, that includes an access to the real data, which implies usually a phase of preparing the real content to be used in the system. This process is called annotation and in order in order to support the objective of adapting the content to each single visitor's profile and visiting experience, semantic information needs to be available both for the audio and multimedia contents. For this reason, ARTSENSE proposes a sophisticated audio annotation tool that enables the possibility of annotating and organizing the different audio contents and sound effects provided to the visitor in an appropriate way, using key-words and themes that are selected by the museum professionals. The Audio Annotation tool is also accessible via the ARTSENSE Metadata Annotation Tool. The Metadata Annotation Tool is designed in such a way so that museum professionals can on their own design and populate the AR tours. More specifically the Metadata Annotation allows to define which details of each artwork will be annotated and with what kind of content. Moreover, the Metadata Annotation Tool stores all of the data that is provided by the museum professionals about the artworks using a semantic model for the artworks with high-level semantic information about each artwork (artwork style, art period, parallels, themes, etc). It is through the hierarchies that are created by the museum curators and educators themselves that ARTSENSE will propose to the visitor the content that seems to better suit the engagement and interest he is manifesting during the visit.

## 4. THE A<sup>2</sup>R MUSEUM VISIT

### 4.1 Identifying Requirements and Needs

If AR can still be considered as an emerging technology, the concept of A<sup>2</sup>R represents an even greater challenge for museums and Cultural Heritage institutions. Thus a lot of collaborative activities occurred, implicating both museum professionals and technology partners so as to comprehend both the particularities of the domain space (the museum environment) as well as the potential of both Augmented Reality and Adaptive Augmented Reality for museum visiting (Damala & Stojanovic, 2012). Among the methods used were on-site observations of museum visits, participatory

observations of guided visits, unobtrusive observations of creative workshops, semi-formal interviews with a large number of museum professionals of different disciplines, brainstorming sessions both in the museum environment and in the lab as well as numerous tests with a large number of AR displays so that the museum professionals manage to get a good idea of the look and feel as well as the advantages and disadvantages of different AR displays. The methodology followed at the early design stages allowed a better comprehension of the potential of AR for the museum visit and also led to the selection of the scenes and the artefacts that each Cultural Heritage partner would augment. The MNAD selected an 18<sup>th</sup> century tiled kitchen from Valencia. The main reasons and motivations as well as a visiting scenario are presented in section 4.2. The Musée des arts et métiers in Paris chose to augment a very challenging artefact/ensemble of objects: The Lavoisier laboratory and the experiment of the synthesis of water. Finally, FACT put forward two projects. In the first one, FACT would augment, the VIP signature Pillar, an architectural element on which VIP guests sign when visiting FACT. The second project will explore the potential of A<sup>2</sup>R under a very different perspective. The international artists collective Manifest.AR has been invited to collaborate with FACT and the consortium. The result of this collaboration will take the form of a dedicated temporary exhibition in which Manifest.AR will explore the potential of A<sup>2</sup>R not as an interpretation and learning medium but as an medium for artistic creation that will embellish not only the FACT exhibition spaces but also the surrounding space of the city of Liverpool in June 2013 (Persing, 2013).

### 4.2 The A<sup>2</sup>R museum visit: MNAD and the 18<sup>th</sup> century Valencian Kitchen

As mentioned earlier, one of most challenging aspects of the ARTSENSE project is the participation of three different Cultural Heritage partners in which the ARTSENSE approach will be tested and validated. In order to provide a more comprehensive example of the Adaptive Augmented Reality museum visit, we will be focusing on the case study of the Museo Nacional de Artes Decorativas, in Madrid, Spain.

The MNAD has an extremely rich collection of Spanish, European and Asian decorative arts. One of its most popular pieces is the so-called "Valencian Kitchen", a complete tiled room from an 18th century palace of Valencia, a Spanish city by the Mediterranean coast (Figure 2). From the medieval times, the area of Valencia was a main centre of ceramic production, and in the 18th century there was a very important tile industry in the city of Valencia. The tiles of the ante-kitchen could have been made in the factory of Alejandro Faure, which was integrated in the Royal Tile Factories of Valencia. We can talk of a phenomenon of tiled kitchens in Valencia as in a period of 125 years there was a great development of this type of decoration. A rich iconography invades these rooms: a great variety of food, cooking tools and narrative scenes are painted on the tiles.

The room is covered with 1,412 tiles, of which 1,382 are antique, original tiles while 130 tiles have been reproduced by the museum during the assembly of the ensemble in a museum gallery specifically conceived and dedicated to the kitchen.

The ARTSENSE project provided a great occasion for revisiting the function of the room. Throughout a period of two years, exhaustive research has been undertaken by art historians and archaeologists in collaboration with the MNAD curators.

Recent studies have demonstrated that the room was not a utilitarian kitchen, but an ante-kitchen, an intermediate room between the kitchen and the dining room, where plates were prepared before offering them to the guests but also a place where guests could meet more quietly after the development of a party (Abad Zardoya, 2013). Also, at this place it took place casual meals as the “refresco” or “agasajo”, a feast that developed from the afternoon until night and in which a great variety of sweets and chocolate beverage were offered to the guests (Coll Conesa, 2013; Alonso Santos, 2011). This kind of celebration was related to family events as marriages, baptisms, mournings and commemorative days as the Corpus Christi, the day of the saint of the city or the patron saint of the house. This ensemble of tiles is very special because only a few of them have been preserved. In the majority of the cases, as is also the case with the MNAD ante-kitchen, the tiles have been removed from their original location while the palace where the MNAD ante-kitchen was placed has now disappeared.

The four walls of the MNAD ante-kitchen are designed as a whole. A garland of flowers and leaves functions as a frame up and down. The profusion of tools and food in addition to the representation of real-size figures enhances the feeling of immersion of the visitor. In the main panel the predominant figure is the lady of the house and her servants; on the left, as we are looking the main panel, we can see a male servant with the shopping basket and two female servants. At first, the visitor can be dazzled by all this visual information he receives. But, if he has some time to fix his eyes on the details, he can imagine that something is happening in this room. The characters are telling us hidden stories that it is necessary to decode.

However, before the beginning of the project, the majority of existing content had the standard form that could be used in a typical audio-guide. This represented a challenge for the conception of meaningful narratives and the overall content creation chain. The museum professionals had to make an effort to conceive and narrate stories, going beyond the traditional, descriptive and linear explanations about the room. ARTSENSE provided an excellent opportunity to work on the interpretation of this room, since the extraordinary visual power of these tiles may prohibit art specialists from realising that it is necessary to meticulously explain to the visitors what kind of work they are looking at.

Once the visitor enters the ante-kitchen, using the ARTSENSE device, he needs some time to place himself in the room. He first starts looking to the walls, then the details and trying to understand what kind of room could this once be. As the system is conceived to provide the information the visitor will seek by tracking his gaze, it was necessary to cater for a short, “compulsory” introduction that the visitor receives once he enters the room. The visitor will receive a video introduction about the room where what is explained is the function of this room, its provenance and chronology. The video shows the geographical situation of the city of Valencia while an old engraving assists the visitor in visualizing how the city looked like in the 18th century. This introduction must be played in all cases, because is the way we have to give to the visitor a minimum reference of what we will be talking about, taking into account that the visitor is at the beginning quite disoriented, as was observed during a front-end public evaluation that was performed in MNAD (Cabrera et al., 2012; Asensio et al., 2012). This is also the reason that at the end of the introduction, ARTSENSE will suggest to the visitor to start with the main panel, where the lady of the house is depicted.

The visitor is now free to explore the panel by observing the scene. However, from this point onwards it is not possible to know or predict which will be the entry point, else the figure and content that the visitor will try to activate so as to get more information. A visitor might as well start the visit by fixating his eyes on the lady, as well as by fixating one of the servants or even the details (tools, garlands, animals). This implies that the content chunks must stay short, must be self-contained and must be able to be combined with other multimedia sequences. For this reason, the museum focused on a principal story line and scenario, destined to adult visitors with the idea that if the adaptation process of the A<sup>2</sup>R is successful and the links among interpreting the feedback of the audio, visual and physiological sensors are mastered, then new content can be prepared for different types of visits or visiting styles.

As a consequence, the museum professionals had to prepare the content to be delivered in the form of stories that adhere to a hierarchy of topics. A big tree of interrelated themes that contain the variety of significances of the decoration of the room was created using the Metadata Annotation Tool. The task was not easy since the subjects and topics that are revealed through the Valencian Kitchen are extremely interrelated. All subjects and topics were organised in hierarchies. Therefore it is possible to offer content either following the principle of thematic tours (“daily life in Valencia in the 18th century”, “household organization”, “18th century parties”) or using the figures and visual elements as key-points for entering in the narratives to be revealed. From an ARTSENSE system point of view, two types of attention can occur: 1. Visual Attention (in direct relation with the observed scene) and 2. Content based attention (related with what is narrated, delivered) (Xu et al., 2012). For example, a visitor might look intensely at the lady of the house. The system is able to recognise exactly the Point of Interest at which the visitor is looking and retrieve if there is any associated content with the detail the visitor is looking at. Thus, if the system detects that the visitor is looking the dress of the lady, the content proposed is “the lady dress”, “18th century fashion”, “the silk industry in the 18th century”, or “the women in the 18th century”. Parallels of the dress, the jewellery or the headdress of the lady can be also provided to the visitor.

The MNAD has a rich collection of exhibits displayed in other rooms and galleries that can be compared with the ones seen on the walls of the ante-kitchen. Hence, semantically, a thematic tour on a theme for which the visitor demonstrated interest, can also go way beyond the Valencian ante-Kitchen, to other parts of the museum collection. Sound and music can be used to enhance the significances and contents we try to transmit. Another form of providing the visitor with engaging content is to work on stories and dialogues among the main principal figures: the black servant talking about her life, a dialogue between the kitchen servants, the lady of the house talking to the servants or to the housekeeper. These personal stories can provide information about the organization of the household, the role of women and men in the 18th century, the 18th century society, etc.

The MNAD proposal is related with the big questions usually a museum visitor makes: what, by whom, how, why and when. These questions connect an object (the ante-kitchen) with its context of creation and appearance trying to give to the visitors a general idea, not only about the object but also, about these aspects that could more fit the interests of each single visitor (e.g. fashion, cooking, society, etc.). If lack of interest is detected, the mechanism of adaptation can propose to the visitor

an alternative narrative style (e.g. propose a dialogue instead of more scholar commentary), another topic or different media (e.g. video, animations). AR content and suggestions about new thematic units are provided by the system according to the visitor's level of interest as inferred from their attention (visual, acoustic) and physiology (interest and engagement).

## 5. A<sup>2</sup>R: ISSUES, CONCERNS, VISITORS' FEEDBACK

Several test and evaluation sessions have so far occurred in all three participating museums and galleries. Some of these sessions had as a goal to advance our understanding about specific system components. For example, one of the experimentations carried out with museum visitors in Paris, Madrid and Liverpool explored the use of eye tracking and eye-triggering of audio sequences about selected artefacts and a combined use of minimally biosensors for gathering physiological data. Other front-end evaluation activities that have been carried out by the MNAD focused on evaluating types of content and narratives that the museum visitors would like to see delivered to them through the system.

In September 2012 the first ARtSENSE prototype was tested informally by approximately 25 users using the Fraunhofer HMD display. The use of the system seemed to be quite intuitive. Gesture interaction was a feature that was particularly appreciated though it seemed that for some of the users selecting an option by gesture interaction did not work as smoothly as for other users. By observing the users interacting with the system, one of the most striking observations was the variety of different gestures employed for pointing and validating a selection on the Augmented Reality scene (Figure 2). Given the variations that we observed, the system responded quite well. However it also became clear that for a smoother interaction, the system will need to be trained and extensively tested among many test sessions that can take place either in a lab environment or the museum. As to the feelings provoked by wearing the AR display, opinions were scattered. Some of the visitors thought that the display was quite heavy and uncomfortable; others thought that the display was comfortable. The addition of a nose-pad will certainly improve the comfort when wearing the glasses. Another important issue that was also an important drawback for carrying out a formal evaluation session was that the prototype that was tested used a red-black instead of an RGB display. As expected this was also noted by several users that complained that it was not possible to see well the projected images.

One of the most greatly appreciated features was the responsiveness of the eye tracking content activation by eye-triggering and the navigation in the content using natural pointing gestures. A very delicate issue that needs to be explored however is the use of biosensors. There is an important trade-off among measurements accuracy and invasiveness while museum visitors may be alienated or bewildered if they are not aware in advance about the use of biosensors. This is an aspect that needs to be further investigated. However, some first findings from the series of eye-tracking and biosensing tests that were carried out in which 36 visitors, representing 4 different age groups, showed that the acceptance rate varied significantly from one Cultural Heritage institution to another, despite the fact that the equipment used was the same in Madrid, Paris and Liverpool. More in particular the FACT visitors in Liverpool seemed to be very keen to test the system and the biosensing equipment and did not seem to be troubled or disturbed by the use of biosensors. The statement

asking the visitors whether they found the biosensing equipment comfortable gave a mean of 4.25/5 in FACT, Liverpool versus 3.58/5 in MAM, Paris. Our interpretation with regards to the different attitudes manifested by the French and British museum visitors are related with the image of the Cultural Heritage institutions but most importantly by the expectations they seem to nurture and create among their public. In short, the character and public of FACT as an institution investing and investigating on the interrelations among Art, Society and Technology seems to attract a public that is willing to test and adopt alternative methods for museum learning and interpretation as in comparison with more conventional or traditional Cultural Heritage institutions.

## 6. DISCUSSION AND DIRECTIONS FOR FUTURE WORK

This contribution introduced the concept of A<sup>2</sup>R and its potential for the museum visiting experience. The novelty of the concept however seems also to introduce a series of issues that will need to be further investigated in an interdisciplinary, ARtSENSE like fashion.

According to the museum professionals of all three Cultural Heritage institutions participating in the project, one of the most challenging aspects in ARtSENSE is the process of content creation. There are indeed many stories that can be narrated but how is it possible to create meaningful, self contained content, referring to one single scene, with multiple entry points, without being able to predict where is it that the story will begin and end? In the future and as more and more visitors will get acquainted with the use of the systems, we might be able to record and observe that schemes or paths of navigation in the existing content may be established. But for the time being the existing content and interpretation material that is being created for ARtSENSE has nothing in common with interpretation materials that could be used for audio-guides or text panels. Could ARtSENSE assist us in better understanding how to create interactive narratives? Could the project have a long term impact on storytelling strategies for museums and Cultural Heritage institutions? Are there any guidelines that can be created given the width of the ARtSENSE approach, covering three Cultural Heritage institutions spanning across three countries? The adaptation of the content proposed in ARtSENSE is a key feature for the A<sup>2</sup>R museum visiting experience and one on which museum professionals will have to make an important contribution.

The adaptation of the content however is also dependent on the use of biosensors. This is a component that –unlike mobile devices or mobile AR applications– might be bewildering for the museum public and the museum institutions. However, psychophysiology has the potential to provide invaluable data and information about the ways through which learning becomes more effective in museums and galleries. And it is reasonable to expect that biosensing devices will progressively become more discrete and accurate. Maybe other, more play-like or creative approaches could assist in demystifying the biosensing technology as is the case with the EEG Things we have lost project of John Craig Freeman developed for the FACT exhibition featuring Manifest.AR (Persing, 2013).

Finally, it is also important to think ARtSENSE not only as a tool for the museum visitors but as a tool for the museum professionals themselves. ARtSENSE provides complex and invaluable features through which museum curators and



educators may assess the impact of the interactive experience they have been tailoring about a museum or gallery artefact. Monitoring, logging and analyzing data coming from the eye tracker for example can provide a wealth of information on the exhibits' attractive and holding power while the same holds true about the multimedia content that is prepared by the cultural heritage professionals. Under this scope and perspective it seems to become more and more clear that within ARtSENSE what is important is not only the final result but also an understanding of the process and the procedures that led us there and the new ways through which we can comprehend and understand the process of learning and meaning making within cultural heritage contexts.

### Acknowledgements

This research was funded by the cooperation programme of the Seventh Framework Programme of the European Commission FP7 – ICT Call 6 – Project Reference 270318.

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