Digital cultural heritage experience in Ambient Intelligence

Nikolaos Partarakis[1], Dimitris Grammenos[1], George Margetis[1], Emmanouil Zidianakis[1], Giannis Drossis[1], Asterios Leonidis[1], George Metaxakis[1], Margherita Antona[1], Constantine Stephanidis[1, 2]

[1] Foundation for Research and Technology – Hellas (FORTH)
Institute of Computer Science
Heraklion, Crete, GR-70013, Greece

cs@ics.forth.gr

[2] University of Crete, Department of Computer Science

Abstract: This chapter presents recent advances in Ambient Intelligence technologies (AmI) for digital heritage experience in the context of Virtual Museums (VM). This is delivered under the light of an integrated and scalable approach towards the creation of AmI heritage environments. More specifically, this chapter presents a framework for representing knowledge and the appropriate mechanisms for personalizing content and user interfaces (UIs) to each individual user of a VM application. Based on the presented framework a number of enabling technologies are reviewed as employed in alternative application contexts to explore: (a) the provision of personalized interaction with artworks, (b) the provision of mixed reality technologies for blending the physical with the virtual world, (c) gamification techniques for educational purposes within the museum context, (d) the usage of gamification as a means to produce interactive art installations and (e) the usage of portable mobile and custom hardware devices as a museum guide and as a means for exploring a museum in the context of a treasure hunt game.

1. Introduction

Today, the term Virtual Museum (VM) is mainly used to describe initiatives such as 2D and 3D digital collections available on the web, virtual tours to existing physical museums or (in its advanced form) a systematic use of web-technology and tools, as well as multimedia content, to communicate aspects of the digital culture and Cultural Heritage (CH)[1]. Recent and current research activities on VMs have identified and systematically advanced new technologies methods and tools to develop the VM of tomorrow. A wide-range of technological challenges related to digital CH have been addressed, including 3D and mass-digitization of tangible artefacts/ artworks (e.g., Scan4Reco[2], 3D-COFORM[3], GRAVITATE[4]), digital repositories, meta-data and preservation policies (e.g., Europeana[5], AthenaPlus[6], DCH-RP[7]), 3D data capture and scanning (e.g., DigiArt[8], GRAVITATE[9]), digitization of intangible cultural content (i-Treasures[10]), authoring and digital storytelling (e.g., CHESS[11]), Virtual Reality (VR) & Augmented Reality (AR) technologies (e.g., DigiArt[12], CHESS[13], iTACITUS[14]), as well as holistic solutions for virtual exhibitions (e.g., AthenaPlus[15]). Access to digital content through mobile and web platforms, adaptability, personalisation and multimodal user interaction have equally been addressed. Furthermore, initiative such as V-Must[16] and eCult[17] have carried out extensive technology watch on VM-related state-of-the-art technologies and applications and have conceived well-documented visions on the VM of tomorrow[18].

Despite this progress, several limitations still exist, such as: (a) lack of technology to enhance and deliver digital content in high quality and in universal formats to reduce compatibility issues, (b) the lack of tools for the development of VMs to reduce the complexity and authoring time, (c) need to integrate the aforementioned technologies under a unified framework for visualizing VMs content, (d) lack of sufficient mechanisms to provide personalized content and (e) lack of adaptation mechanisms to present a suitable user interface to individual users of the VM.

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[1] Examples of existing Virtual Museums can be found at http://www.v-must.net/virtual-museums (V-musT.net is a NoE funded by FP7; end date 31/12/15)

[2] http://scan4reco.eu/scan4reco/

[3] http://www.3d-coform.eu/

[4] http://gravitate-project.eu/

[5] http://www.europeana.eu/portal/

[6] http://www.athenaplus.eu/

[7] http://www.dch-rp.eu/

[8] http://digiart-project.eu/

[9] http://gravitate-project.eu/

[10] http://i-treasures.eu/

[11] http://www.chessexperience.eu/

[12] http://digiart-project.eu/

[13] http://www.chessexperience.eu/

[14] http://www.instantreality.org/itacitus/

[15] http://www.athenaplus.eu/

[16] http://www.v-must.net/

[17] http://www.ecultobservatory.eu/tech-catalogue/tech-solutions/all and http://www.v-must.net/technology

[18] http://www.v-must.net/library/documents/d31-theory-design-updated-2014, http://www.ecultobservatory.eu/documents

This chapter presents a framework for implementing digital cultural heritage application on top of AmI technologies supporting rich interaction and gamification. Based on the presented framework, a number of enabling technologies are reviewed as employed in alternative application contexts.

2. Background and related work

2.1. Virtual Museums

VMs have evolved from digital duplicates of “real” museums or online museums into complex communication systems, strongly connected with narratives, interaction and immersion in 3d reconstructed scenarios [15]. Currently existing VMs can be classified as:

- **Mobile VMs or Micro Museums:** Mobile applications to explain history, architecture and or other artworks visually (indoor virtual archaeology, embedded virtual reconstructions etc.)
- **On site interactive installations:** Multi-user environments, aimed at conserving the collective experience typical of the visit to a museum. A common characteristic is the use of 3D models reconstructing monuments, sites, landscapes, etc., which can be explored in most cases in real time, either directly or through a guide [16].
- **Web-delivered VMs:** Virtual Museums providing content through the Web. A wide variety of 3D viewers and players have been developed to provide 3D interactive applications “embedded” in browsers, activated by website exposing specific 3D content. Examples include: Google Art, Inventing Europe, MUSEON, etc.
- **Multimedia VMs:** They involve interactive experiences blending video, audio and interactive technologies, usually delivered via CD-ROM or DVD (for examples 'Medieval Dublin: From Vikings to Tudors').
- **Digital Archives:** Increasingly popular, as the amount of digital information increases, together with the wish of the public to gain access to information. Examples include: thesaurus of terms, digital repositories considering all possible different metadata schemes, intelligent searching / browsing systems etc.
- **VMs can be classified by:** (a) **Content,** referring to the actual theme and exhibits of a VM (history, archaeology, natural history, art, etc.), (b) **Interaction Technology,** related to the user capability of modifying the environment and receiving a feedback to his/her actions (both immersion and interaction concur to realize the belief of actually being in a virtual space [17]), (c) **Duration,** referring

to the timing of a VM and the consequences in terms of technology, content, installation, sustainability of the projects (Periodic, Permanent, temporary), (d) **Communication,** referring to the type of communication style used to create a VM. Can be classified in: Descriptive, Narrative or Dramatization-based VMs, (e) **Level of user Immersion**: Immersive, and non –immersive [17], (f) **Sustainability level**, i.e. the extent to which the museum software, digital content, setup and/or metadata are **r**eusable, portable, maintainable, exchangeable, re-usable, (f) **Type of Distribution** refers to the extent to which the VM can be moved from one location to another. It may include *mobile VMs* and *non-distributed VMs* (e.g. on-site installations) and (g) **Scope of the VM**, including Educational, Entertainment, promotional and research.

2.2. Knowledge models for CH

In the Cultural Heritage Domain, the use of ontologies for describing and classifying objects is now a well-established practice. The Getty vocabulary databases, maintained by the Getty Vocabulary Program, provide a solid basis that is a de facto standard in the area[19]. These databases are thesauri compliant with the ISO standard for thesaurus construction. They comprise: the Art & Architecture Thesaurus (AAT), the Union List of Artist Names (ULAN) and the Getty Thesaurus for Geographic Names (TGN). The AAT, in particular, contains more than thirty thousand concepts, including terms, descriptions, bibliographic citations and other information relating to art. The AAT is organized as a hierarchy with seven levels, called facets, in which a term may have more than one broader term. The Getty Research Institute has also developed a metadata schema, called the Categories for the Description of Works of Art (CDWA), for describing art works. CDWA includes 381 categories and sub- categories, a small subset of which are considered core, in the sense that they represent the minimum information necessary to identify and describe a work. Complementary to CDWA, the Conceptual Reference Model (CRM) of the International Committee for Documentation of the International Council of Museums (ICOM-CIDOC) has emerged as a conceptual basis for reconciling different metadata schemas[20]. CRM provides definitions and a formal structure for describing the implicit and explicit concepts and relationships used in cultural heritage documentation. CRM is an ISO standard (21127:2006) that has been integrated with the Functional Requirements for Bibliographic Records (FRBR) and the Europeana Data Model[21], which plays the role of upper ontology for integrating metadata schemes of libraries, archives and museums.

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[19] http://www.getty.edu/research/tools/vocabularies/index.html

[20] http://www.cidoc-crm.org/

[21] http://pro.europeana.eu/web/guest/edm-documentation

2.3. Interactive technologies for Virtual Museums

Virtual Reality (VR): VR provides total sensory immersion through immersion displays, tracking and sensing technologies. Common visualization displays include head-mounted displays and 3D polarizing stereoscopic glasses while inertia and magnetic trackers are the most popular positional and orientation devices. As far as sensing is concerned, 3D mouse and gloves can be used to create a feeling of control of an actual space. An example of a high immersion VR environment is Kivotos, a VR environment that uses the CAVE® system, in a room of 3 meters by 3 meters, where the walls and the floor act as projection screens and in which visitors take off on a journey thanks to stereoscopic 3D glasses [18]. As mentioned earlier, virtual exhibitions can be visualized in the Web browser in the form of 3D galleries, but they can also be used as a stand-alone interface. In addition, a number of commercial VR software tools and libraries exist, such as Cortona [19], which can be used to generate fast and effectively virtual museum environments. However, the cost of creating and storing the content (i.e., 3D galleries) is considerably high for the medium and small sized museums that represent the majority of CHIs.

Augmented Reality (AR): In addition to VR exhibitions, museum visitors can enjoy an enhanced experience by visualizing, interacting and navigating into museum collections (i.e. artworks), or even by creating museum galleries in an AR environment. The virtual visitors can position virtual artworks anywhere in the real environment by using either sophisticated software methods (i.e., computer vision techniques) or specialized tracking devices (i.e., InertiaCube). Although the AR exhibition is harder to achieve, it offers advantages to museum visitors as compared to Web3D and VR exhibitions. Specifically, in an AR museum exhibition, virtual information (usually 3D objects, but also any type of multimedia information, such as textual or pictorial information) is played over video frames captured by a camera, giving users the impression that the virtual cultural artworks actually exist in the real environment. AR has been experimentally applied to make it possible to visualize incomplete or broken real objects as they were in their original state by superimposition of the missing parts [20]. The ARCO system [21, 22] provides customized tools for virtual museum environments, ranging from the digitization of museum collections to the tangible visualization of both museum galleries and artworks. ARCO developed tangible interfaces that allow museum visitors to visualize virtual museums in Web3D, VR and AR environments sequentially. A major benefit of an AR-based interface resides in the fact that carefully designed applications can provide novel and intuitive interaction without the need for expensive input devices.

Mixed reality (MR): MR relies on a combination of VR, AR and the real environment. According to Milgram and Kishino's virtuality-continuum, real world and virtual world, objects are presented together on a single display [23] with visual representation of real and virtual space [24]. An example of the use of MR techniques in a museum environment is the Situating Hybrid Assemblies in Public Environments (SHAPE) project [25] that uses hybrid reality technology to enhance users' social experience and learning in museum and other exhibition environments, with regard to cultural artworks and to their related contexts. It proposes the use of a sophisticated device called the periscope (now called the Augurscope), which is a portable MR interface, inside museum environments to support visitors interaction and visualization of artworks.

2.4. Gamification techniques for digital cultural heritage

Gamification is the use of game thinking, game mechanics, as well as game dynamics and frameworks in a non-game context in order to engage users, solve problems, improve user experience, and promote desired behaviors [12].This can be achieved by using techniques from the fields of psychology and game design. It is used to improve timelines and learning.
Museums are considered ideal environments for experimenting with informal learning technologies [42]. In terms of game based learning treasure hunts, mysteries, and puzzles are common in museums, as is the use of mobile devices to guide and facilitate the collecting of exhibition information to collaboratively solve tasks. A familiar approach is seen in the design of Mystery at the Museum at the Boston Museum of Science [43]. In designing learning games that both engage and support inquiry across school and museum contexts, mobile social media, 'smartphone' technologies, and ubiquitous Internet access have been pivotal developments [44, 45]. However, finding a balance between guided and open activities, and structuring opportunities for social interaction and collaboration are important when designing mobile applications for informal learning settings [46].

3. A state of the Art AmI framework for Digital Cultural Heritage

In this chapter a state of the Art AmI framework for Digital Cultural Heritage is presented. This framework is based on AmI technologies and comprises a set of reusable tools and components used across a number of programming languages and tools for the development of interactive systems for cultural heritage. Three are the major facilities offered by this framework: (a) a transparent way to provide seamless interaction between software components and services, (b) a knowledge representation framework to support uniform data storage and exploitation from alternative services and programming languages and (c) a pool of reusable interaction modalities based on a suite of image recognition and vision technologies. A high level architecture of the framework is presented in figure 1.

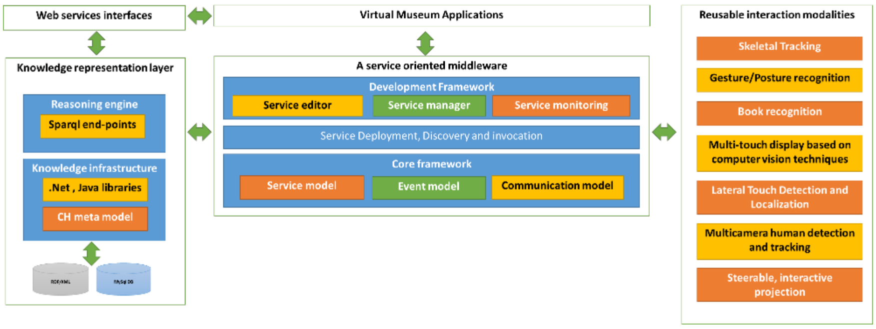

Fig. 1 High level architecture

3.1 A service oriented middleware

At a technical level, ambient Intelligence (AmI) environments are comprised of a large number of diverse heterogeneous computing systems that constantly interoperate in order to provide a unified and seamless user experience. The comprising computing systems are inevitably heterogeneous, since they cut through many different research domains with many different requirements, goals and capabilities. Requiring all the constituent components to be exclusively developed using a universal set of software and hardware technologies is impractical due to performance, suitability, sustainability and, of course, reusability reasons. Towards this direction, we addressed the issue by developing a software platform that lies between all the diverse computing systems and the applications that utilize them and provides a common consistent view and access methods of the former to the latter, regardless of their implementation technologies [39]. This software platform is referred to as the Service Middleware for AmI environments.

The service middleware ecosystem comprises of the following four software components: (a) software libraries for facilitating communications and service distribution, (b) a set of core services for providing discovery and deployment functionality for the services infrastructure, (c) development tools that facilitate the creation, usage and deployment of services, and (d) client programs for managing and monitoring the computers that are used for running services [40].

3.2 A knowledge representation layer

In the proposed framework, knowledge is handled through an ontology model. Although the structure of the ontology is modelled using OWL [41], the actual data are stored either in an XML/OWL format or in a MySQL relational database. The model gets exported to the higher levels of the architecture through a set of programming language classes developed either manually using c#, either automatically through the protégé [29] data export facilities. Reasoning engine rules have been defined on the knowledge model using Jess [30]. Two sparql query engines have been defined: one that uses the SemWeb.Net library [28] and one using Jena [27] and Pellet [26]. These query engines submit SPARQL queries to the ontology and the results of these queries are retrieved in XML and deserialised into meaningful instances of the model. The knowledge infrastructure is exposed to different programming languages and tools in alternative ways: (a) as a middleware service for allowing access from all deployed services, (b) as an IIS and an Apache Tomcat web service to be used by applications not running on the middleware but with support for web services and (c) as a class library both in .Net and Java for direct integration and usage by applications.

3.3 A pool of reusable interaction modalities

The framework facilitates alternative forms of interaction that employ the full set of human perceptual capabilities in order to improve interactive user experience. . A pool of reusable computer vision components is employed, each one offering an alternative form of interaction:

- **Skeletal Tracking:** The Skeleton tracking component reports the position information of each skeleton joint. This component performs geometric transformations on each skeleton joint position constituting every real time skeleton frame. This happens in order to get the same valid results regardless of the position of the user who may be located everywhere inside the sensor's field of view [34].
- **Gesture/Posture recognition:** The Gesture/Posture recognition module implements the dynamic time warping (DTW) algorithm [33] for measuring similarity between two skeleton sequences which may vary in time or speed. Additionally, it provides a training platform that allows developers to fine tune their gestures having access to a number of alternative biometric parameters [34].
- **Book recognition:** This component is capable of performing recognition of book pages and of specific elements of interest within a page, as well as to perceive interaction with actual books and pens/pencils, without requiring any special interaction device [32].

- **Multi-touch display based on computer vision techniques:** A multi-touch display based on computer vision techniques. The developed system is built upon low cost, off-the-shelf hardware components and a careful selection of computer vision techniques. The resulting system is capable of detecting and tracking several objects that may move freely on the surface of a wide projection screen. It also provides additional information regarding the detected and tracked objects, such as their orientation, their full contour, etc. [31].
- **Lateral Touch Detection and Localization:** Fingertip contact detection and localization upon planar surfaces to provide interactivity in augmented displays implemented upon these surfaces, by projector-camera systems. In contrast to the widely employed approach where user hands are observed from above, lateral camera placement avails increased sensitivity to touch detection [8].
- **Multicamera human detection and tracking:** A computer vision system that supports non-instrumented, location-based interaction of multiple users with digital representations of large-scale artifacts. The proposed system is based on a camera network that observes multiple humans in front of a very large display. The acquired views are used to volumetrically reconstruct and track the humans robustly and in real time, even in crowded scenes and challenging human configurations [5].
- **Steerable, interactive projection:** Technology to produce a steerable, interactive projection display that has the shape of a disk. Interactivity is provided through sensitivity to the contact of multiple fingertips and is achieved through the use of a RGBD cameras. The surface is mounted on two gimbals which, in turn, provide two rotational degrees of freedom. Modulation of surface posture supports the ergonomy of the device but can be, **alternatively**, used as a means of user-interface input. The geometry for mapping visual content and localizing fingertips contacts upon this steerable display is provided, along with pertinent calibration methods for the proposed system [7].

4. Applications and their deployment in CHIs

This section presents a collection of interactive applications in the context of cultural heritage institutions that explore the proposed AmI framework. These applications are grouped based on the provision of similar functionality to end users in the following categories: (a) personalized interaction with artworks, (b) Mixed Reality technologies, (c) gamification techniques for educational purposes, (d) interactive art installations and (e) portable mobile and custom hardware devices.

4.1. Personalized interaction with artworks

This section presents interactive systems that augment digital reproductions of artefacts to offer personalized interaction. These systems are used to present digital artefacts that are not physically exhibited in museums due to their nature (e.g., murals inside protected monuments).

Interacting with large digital reproductions of murals

Macrographia (see Fig. 2) is a system that presents very large images, which visitors can explore by walking around in a room. The images are projected on a screen which takes up one wall of the room and are analysed part-by-part depending on the location of each visitor in the room. Visitors enter the room and the system follows the movement of each one separately. When someone stands in front of a section of the image, depending on the distance from the screen, the section of the image she/he views and the caption underneath changes. There are several layers of information, depending on the size of the room. Visitors can select the language of the accompanying text by entering the room from the left or right side [4].

The system is installed in a room in which a computer vision system tracks the position of visitors [3, 5]. Macrographia can present large scale images of artifacts, with which one or more visitors can concurrently interact by walking around. Visitors enter the room from an entrance opposite the display. The vision system assigns a unique id number to each person entering the room. As help signs illustrate, visitors entering the room from the right-hand side are considered to be speakers of one language, for example English, while those from the left-hand side of another, for example Greek. When at least one person is in the room, a piece of music starts to play. The room is conceptually split in several zones of interest, delimited by different themes presented on the projected image. These zones divide the room in vertical slices. The room is also split in several horizontal zones that run parallel to the projected image, which are delimited by their distance from it. Thus, a grid is created, comprising many interaction slots. When a visitor is located over a slot, the respective projected image part changes and, depending on the slot's distance from the wall, visitors can see enriched images, accompanied by related information.

All information is presented in the user's preferred language. Since users are associated with a unique id, the system keeps track of the information they have accessed, as well as of the time they have spent on each slot.

Apart from location-sensing, Macrographia also supports two additional types of interaction: (a) a kiosk and (b) mobile phones. The kiosk offers an overview of the projected image, an introductory text and two buttons for changing the user's language. All information is automatically presented in the visitor's preferred language. Furthermore, the wall piece in front of which the visitor has spent most of the time is highlighted. Mobile phones are used as multimedia guides, automatically presenting images and text (that can also be read aloud) related to the visitor’s current position.

Fig. 2 Macrographia installation “Archaeological Museum of Thessaloniki”

Interaction type	Body tracking	Number of users	No limitation
Size	6x2 m	Usage	Projection of large murals
Complexity	2 projectors 1pc 4 depth cameras	Approach	Multicamera human detection

Interacting with digital reproductions of paintings

The “Personalised Multi-user painting” is a suite of tools to allow the augmentation of interaction with paintings using a collection of alternative interaction devices (projection, portable devices, mounted displays). Its purpose is to provide interaction where no interaction exists (making physical artefacts interactive) and provide interactive digital artefacts where no artefacts exist (importing both an artefact and the means to interact with it within the Cultural Heritage Institutions experience) [2]. It comprises a number of devices for content provision as long as a number of modalities for interaction. As shown in figure 3, the main section of the exhibition wall is occupied by a digital representation of an exhibit in two variations. The first variation is a fully digital exhibit where the exhibit itself is projected through the usage of a short throw projector, while the second one is an actual physical painting. In both cases skeleton tracking is used to track the location and distance of visitors. The installed tracking technology supports the presentation of information about points of interest using body tracking (two visitors are supported on the body tracking mode while three are supported for the hand tracking). At the sides of the exhibit, two tablets are mounted on the wall or on two portable stands to act as captions of the painting. The captions, based on the visitor profiles, present various information such as description, videos, points of interests, deep zoom representation of the painting, full artefact info and information from external sources. These tablets are also equipped with embedded web cameras for QR code recognition. Visitors' mobile phones are used for accessing information about the exhibit by scanning the QR codes (from the captions). Portable tablets, rented or carried by visitors, can also be employed as information displays.

Fig. 3 The interactive digital exhibit.

Interaction type	Body Tracking and touch	Number of users	2 with body tracking 2 using tablets 2 using captions Unlimited using (mobile phones)
Size Complexity	Variable 1 projectors 4 tablets 1 depth cameras Unlimited mobile phones	Usage Approach	Projection of painting Single camera body tracking

4.2. Mixed reality technologies

The term Mixed Reality technology in this chapter is used to denote the mixing of physical artefacts and machinery with digital information and interactive systems to produce a unique sensory experience.

Augmenting traditional games with non ICT

The mixed reality game presented in figure 4 is a collaborative game where children can solve puzzles either in a cooperative or in a competitive mode [10]. Between the two large touch displays there is a wooden ball game activated through a rotating physical controller. When the ball is activated by the controller, it is transmitted via the displays (in its digital form). There the virtual avatar of El. Venizelos, a Greek politician of the early 20th century, appears with a golf club to push the ball back to its physical form. Then through the game the ball enters the second display and falls within a golf hole to appear again in its physical form in the wooden game setup.

Fig. 4 An interactive puzzle game for children "House of El. Venizelos city of Chania"

Interaction type	Multi-touch	**Number of users**	Maximum 10
Size	Wall 5x2.5 meters	**Usage**	Cooperative gaming
Complexity	2 screens 55" One physical ball game Various Sensors	**Approach**	Distributed service oriented communication of devices

Making traditional artefacts interactive

Oil Mill is an innovative interactive system presenting traditional Cretan products and recipes. Oil Mill incorporates a miniature stone mill, through which it is possible to browse through an introduction to Cretan diet and cooking. Users can browse through a digital album about Cretan diet, by rotating the metal handle of the mill, while real oil flows from one end of the system. Users can also send information provided by the system (e.g., recipes, information about traditional products) by e-mail. The system also comprises lighted glass showcases containing museum replicas of pottery.

Oil Mill aims at providing information related to Greek culture and tradition, combining real traditional artifacts with digital content. The technology that lies underneath the system is able to augment any physical object towards natural user interaction for browsing digital content related to a specific thematic area (e.g., Cretan diet as show in figure 5).

Fig. 5 An exemplary setup of the oil mill "Kazantzakis airport of Heraklion"

Interaction type	Multi-touch	**Number of users**	Single user
Size	Depends on the physical exhibits	**Usage**	Augmentation of physical artefacts
Complexity	1 touch screen 32" 1 touch screen 22" Sensors	**Approach**	Interaction with digital media through physical objects

Alternative forms of interaction with terrain-based information

PaperView is a **tabletop augmented reality** system that supports the exploration of **terrain-based information** (e.g., areas of interest on a 2D map, or a 3D scale model) using rectangular pieces of **plain cardboard**. The system allows users to study information and interactive multimedia, using the cardboards as individual interactive screens; these cardboard screens can be lifted and held at various angles. Multiple users can concurrently use the table [6]. When a user places a cardboard piece over the table surface, an image is projected on it, adding detail to the surface image. Furthermore, a pointer (i.e., a magnifying glass) is projected on the paper's center, which assists the user in exploring the surface, guiding her/him to the information hotspots available. When a hotspot is selected, a multimedia slideshow starts. The slideshow comprises a series of pages, each of which may contain any combination of text, images, and videos. At the bottom area of the slideshow, a toolbar is projected containing an indication of the current page and the total number of pages available, as well as buttons for moving to the next/previous page.

Fig. 6 Paper view "Heraklion info-point"

Interaction type	Cardboard for information display and touch	**Number of users**	Maximum 8 (limited by the size of the table)
Size	Table 1x2 meters	**Usage**	Augmentation of terrain based information
Complexity	Projector, high res camera	**Approach**	Augmentation of analogue media with information And touch based interaction on non-technological surfaces

Interacting with moving surfaces

360[2] is an interactive installation that supports exploring artifacts through physical and multitouch interaction with a **double rotating gimbal** (i.e., a non-instrumented disk that can dynamically rotate around two axes) [7, 9]. While the user manipulates the disk, the system uses a projector to visualize a display upon it. A depth camera is used to estimate the pose of the surface and multiple simultaneous fingertip contacts upon it. The estimates are transformed into meaningful user input, availing both fingertip contact and disk pose information. Besides the provision of **augmented multitouch interaction**, such an achievement can serve two distinct functions. On one hand, the rotation mechanism can be used as a means for easily and intuitively browsing and interacting with alternative, dynamically changing, projection views. On the other hand, the high flexibility and extensive range of projection poses supported by the system can be used in order to dynamically personalize the physical properties of an interactive projection surface to the ergonomic preferences and needs of users.

Fig. 7 The rotating disk system presenting the numismatic collection of Alpha Bank "Archaeological museum of Thessaloniki"

Interaction type	Single-touch	**Number of users**	Sigle user
Size	Depents on the size of the disk	**Usage**	Presentation of dual sided rounded objects and or 3D models
Complexity	1 projector 1 depth sensor 1 high res camera	**Approach**	Touch based interaction on non-technological surfaces

4.3. Gamification techniques for learning purposes

This section presents the use of Gamification techniques for educational purposes in Cultural Heritage settings. More specifically, the systems presented in this section are: (a) interactive wall based games, (b) digital word games that can deliver educational info, (c) interactive animations, (d) interactive game surfaces for children and (e) immersive representations of information.

Interactive "wall based" games

Interactive "wall based" games are defined as games that can be played standing in front a projection which is the game screen and can use their body as the input controller. The Interactive Wall supports **games** that can played by one, two or more players simultaneously, using their entire body, in a space of about 3 x 3 m comprising a large projection area. Players control the game using their **"virtual" shadows** which are projected on the screen and follow their **body movements** [37, 38]. The rationale for using the players' shadow is two-fold. On the one hand, it is easier for people, especially "non game-players", to identify their shadow rather than an avatar, thus achieving a higher level of control and immersion. On the other hand, this approach allows for maximum flexibility regarding the number, posture and size of players, as well instantly joining and leaving the game, thus maximizing the opportunities for social interaction. Players have to use their shadows to direct specific items in (e.g., products) or away from (e.g., garbage) their baskets. Also, in some game variations players may also have to put different items in each different basket (see figure 8).

Fig. 8 Interactive wall "House of El. Venizelos city of Chania"

Interaction type	Full body interaction	Number of users	Maximum that can fit in front of the projection
Size	3x2 meters	Usage	Shadow based games
Complexity	1 project and 1 depth camera	Approach	Interaction with virtual shadow

Playing with words

Cryptolexon, the hidden crossword puzzle, combines entertainment with knowledge. Within the matrix of letters, significant words are hidden. Once a word is discovered, multimedia information about it is displayed. The system uses a touch screen. Users can find the hidden words on the touch screen by dragging their finger from the start to the end of each word or, alternatively, by touching each word's first and last letter.

Fig. 9 Cryptolexon "House of El. Venizelos city of Chania"

Interaction type	Touch	Number of users	Single user
Size	Depends on the installation the minimum is the size of a 32" touch display	Usage	Word based gaming
Complexity	1 touch display	Approach	Puzzle gaming

Learning through interactive animations

Interactive animations can be used to produce game-like edutainment experiences in the context of cultural heritage institutions. An example is the technology kiosk installed at the Archaeological museum of Heraklion where children can learn how ancient metallic and clay items were created. To do so, children should successfully complete a series of mini games that interleave animations with riddle solving parts. An example of the “Ancient Technology Kiosk” is presented in figure 10.

Fig. 10 left: Interacting with animated character. Right: presentation of educational material

Interaction type	Touch	**Number of users**	Single user
Size	Depends on the installation. Minimum is the size of a 32” display	**Usage**	Interaction with animations
Complexity	1 display 32”	**Approach**	Gaming

Experimenting with interactive surfaces for children

Interactive surfaces can be employed by Cultural Heritage Institutions to augment the experience provided to visitors through an easy to deploy and maintain single digital exhibit. An interactive surface comes with embedded applications that can be personalized to meet the demands of third parties or integrate new applications on demand. Furthermore it can integrate a number of ready to use hand crafted physical objects that are used for interacting [12].

A setup of such an interactive surface can embed a number of applications (see figure 11), such as:

- The **Art River**: A river of information that users can interact with. Interaction happens through augmented rocks interlinked with information elements.
- The **Museum Coffee Table**: A place where parents get access to more information about exhibits while children get entertained through games.
- The **puzzle**: An interactive puzzle, inspired by the lives and works of famous Artists.
- **Pick and Match**: A card-based memory game employing cards with art content.
- The **Art Collector**: An augmented board game in which players are asked questions regarding artistic creation facts and locations for each continent.
- **Paint-it**: A painting application allowing children to make their first steps in painting by exploring and learning the principles of color theory.

The Art Collector

Paint-it for children

Pick and Match

Fig. 11 A suite of games for the interactive surface

Interaction type	Multi touch and physical objects	**Number of users**	<30
Size	A 42” sized table	**Usage**	Table based edu-games
Complexity	A multi-touch table with object recognition capabilities	**Approach**	Interaction through the usage of physical objects

Interacting with immersive representations of information

Immersive environments integrating information that can be explored by users have been explored as a means of producing alternative experiences for CHIs. TimeViewer is an interactive system that presents information with temporal characteristics in a large scale display, while user interaction is achieved through remote gestures [11]. Besides representing information as a traditional two- dimensional timeline, the system also supports three- dimensional information representation in a “time-tunnel”, i.e., a corridor along which the events are placed with chronological order. User interaction in the time-tunnel is accomplished through full-body kinesthetic interaction. TimeViewer offers a rich and immersive visualization of any kind of temporal information. The content of the system can be provided through existing formal data models, while the visualization is automatically created (see figure 12).

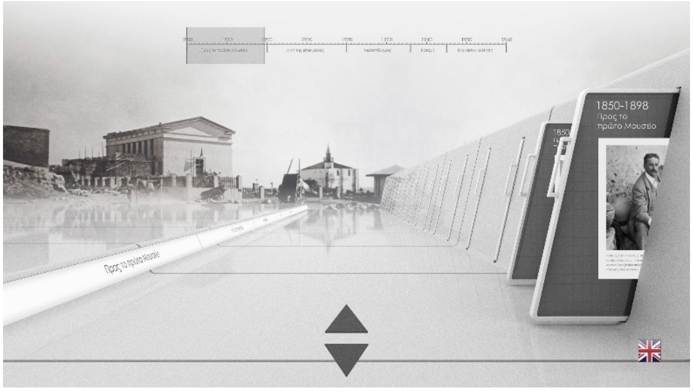

Fig. 12 TimeViewer “Archeological museum of Heraklion”

Interaction type	Hand tracking, Gestures	**Number of users**	Single user
Size	3x2 meters	**Usage**	Visualization of timelines
Complexity	1 projector and 1 depth camera	**Approach**	Interaction with information in immersive environments

4.4. Interactive Art Installations

In this section interactive art installations are presented. These installations combine art and ICT while several hardware controllers and mechanical devices are used as a means of empowering interaction with art. This is achieved through the provision of alternative forms of interaction with digital content and mechanical devises that are integrated within the artwork. The output of this interaction is both digital (altering the content presented by the artwork), electrical (e.g., altering the lighting scheme for revealing “secret” areas) and mechanical (e.g., setting mechanical elements to movement).

An interactive artwork inspired by the history of the city of Heraklion

At the main info-point for visitors of the city center of Heraklion a composition that combines technology and art was created as a means to produce a focal point not only for the historical building of the Vikelaia public library but also for the city center. This was materialized through a double sided sculpture where visitors can interact from within the info point. This interaction is mirrored on the outer side and viewed by the people walking by in the historical center of the city. Inspiration for this work of art was the mythical labyrinth, texts from N. Kazantzakis and the cultural tradition of the city. Visitors are invited to touch the mechanical devices embedded in the sculpture so as to reveal the scripture and set the ancient device back to life.

Fig. 13 Interactive sculpture inspired by the history of the city of Heraklion “Heraklion info-point”

Interaction type	Manipulation of physical objects embedded in the artwork	**Number of users**	Maximum 4
Size	4x3 meters	**Usage**	Interactive art
Complexity	4 displays Led lighting Hardware parts Electronics Analogue moving parts	**Approach**	Interaction with physical controls to produce digital output

An interactive sculpture inspired by the Phaistos disk

At the Kazantzakis airport of Heraklion an interactive sculpture was build inspired by the ancient disk of Phaistos. The main idea of the exhibit was the presentation of the disk through the mixture of the depicted symbols within a large space of 6 x 6 meters. The sculpture is build using a collection of hand crafted cubes each one containing computer controlled internal lighting and in each side the symbols from the disk. The main area of the sculpture is occupied by a large interactive display where users can browse multimedia content using hand tracking. While interacting the sculpture is activated and various light patterns are employed to give movement to the composition.

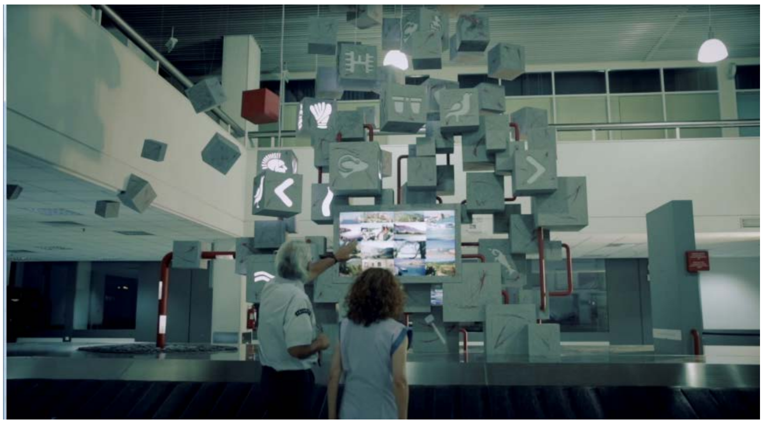

Fig. 14 Interactive sculpture inspired by the ancient Phaistos disk “Heraklion Kazantzakis Airport”

Interaction type	Hand tracking	**Number of users**	One in each side
Size	6x2x6 meters	**Usage**	Interaction with art while browsing information
Complexity	2 displays 2 depth camera Led lighting Various sensors and electronic devices	**Approach**	Combining information with art

An interactive sculpture inspired by the Antikythera Mechanism

An impressive metal structure has been created and installed upon one of the conveyor belts of the airport of Chania. The sculpture also integrates two large displays where the users can interact from distance using hand gestures. Interaction gives movement to the composition and a combination of mechanichal elements, lights and micro devices contribute to a unique experience not only for the users, but also for all people standing by the conveyor belt as shown in the following figure.

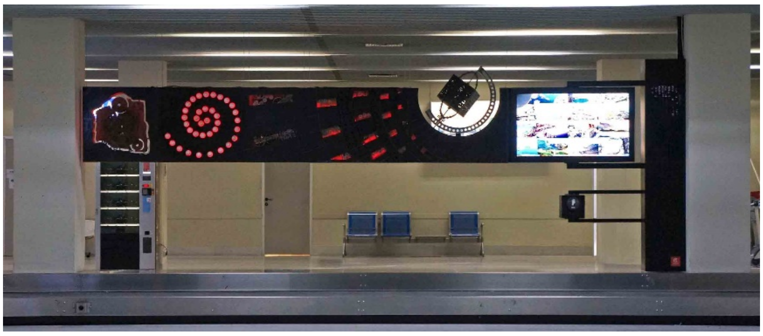

Fig. 15 Interactive sculpture inspired by the Antikythera mechanism "Chania Daskalogiannis Airport"

Interaction type	Hand tracking	**Number of users**	One in each side
Size	6x1x3 meters	**Usage**	Interaction with art while browsing information
Complexity	2 displays 2 depth camera Led lighting Various sensors and electronic devices	**Approach**	Combining information with art

4.5. Portable mobile and custom hardware devices

This section presents technologies that can be considered as mobile devices for CHIs , including both applications that are installed and run in the visitor's mobile phone or custom hardware devices that are provided to visitors by the CHI.

Museum Guide

The "Museum Guide" is a mobile application that can be installed on user-owned mobile devices. The main purpose of this system is to take advantage of the nearubiquity of mobile devices to create a rich museum touring guide that escorts the user during their visit to a museum [14].

More specifically, the visitors' experience is enhanced through (see figure 16):

- Area Information and Guidance: visitors are able to identify, with relative precision, where they are located within the museum and can easily find their way around it, whether they wish to visit a specific exhibition room or a utility area of the building.
- Thematic Information: visitors can receive detailed information (i.e., textual descriptions, photographs, audio and video content) regarding the museum's permanent and any temporary exhibitions, its collections as well as individual exhibits.
- Tour Creation: a set of predefined tours, focusing on specific collections or exhibits, is available to the visitor.

In order to identify the visitor's location in the museum, the use of QR Codes was adopted. Each public building area (e.g., Cafeteria, Gift shop, WC, etc.) has been assigned its own code, as has each individual exhibit within the museum. Through the use of their device's built-in camera, a visitor can inform the application of their current location or identify an exhibit they may be interested in finding more about.

With always-available information and multimedia regarding all exhibits and other points of interest and the ability to tailor their experience to their needs, visitors are essentially accompanied by a comprehensive, intelligent guide that makes their museum experience not only richer, but also more efficient.

Fig. 16 Left: A route defined by the visitor, Right: Overview of a tour

Interaction type	Touch	**Number of users**	Single user
Size	Size of Handheld device	**Usage**	Terrain based information
Complexity	Handheld device	**Approach**	Terrain and POIs visualization

Employing custom hardware devices for exploratory learning

Infoscope is a novel mobile device that can support knowledge discovery and exploratory playing in physical environments. Infoscope utilizes RFID technology to provide audio guiding and localized question / answer games, while it employs wireless communication technologies to exchange information about its user's interests with computer platforms and to present through them related supplementary multimedia information. The device comes with two accompanying software components: one for editing / updating its contents, and one running on personal computers for providing supplementary multimedia information [13].

Infoscope integrates RFID reading capabilities and can play related audio information which can be adapted to its user's profile (e.g., language, age, interests). The device is embedded in an ergonomically-designed shell and is extremely easy to use, as it mimics the use of a typical doctor's stethoscope. When a user is interested into a specific item, all she has to do is to put the device over a related RFID tag in order to listen to a corresponding audio description. Additionally, by "listening to" appropriate tags, the user can adapt the audio descriptions to her personal profile traits. Beyond localized information presentation, Infoscope supports exploratory gaming in physical environments through question / answer games, where a tag is used to trigger a question that has to be answered by "listening to" the tag of the corresponding place / item and has been installed at the House of El. Venizelos at the city of Chania in the context of the museums educational activities for children as shown in the following figure.

Fig. 17 Infoscope device and PC docking station "House of El. Venizelos city of Chania"

Interaction type	Touch using the device on RFID tags	**Number of users**	Single user
Size	5x5x15 cm	**Usage**	Presentation of tagged audio information
Complexity	Portable info-scope Docking station with charging station and touch display	**Approach**	Interaction using portable audio guides

5. Lessons learned

This chapter presents an AmI framework employed in the context of various interactive applications hosted over the years in numerus installations. This framework should be considered a living organism that was not developed in its current state from the beginning but rather evolved in its current state through an evolutionary process that involved allot of experimentation, trial and error. The main building block of the success of this framework was that it was designed by the beginning to be simple, powerful and expandable. Prior to producing anything the need for a service oriented infrastructure that could unite heterogeneous computing components, applications, services and sensors was visualized. This was substantial and was materialized in the form of a distributed service oriented middleware that could support any computing platform, software development toolkit and programming language. The middleware was developed as a separate product from the beginning and tested so as to ensure that the glue for developing truly distributed AmI environments and applications existed. Then the second step was to envision how interaction would be bound to applications in such environments so as to ensure that applications will still operate under any circumstances and regardless of the way that the user desire to interact (hand tracking, touch, gestures etc.). To achieve a total separation of the interaction modalities with the systems receiving input a decision was made to develop autonomous pluggable service oriented modalities that would become available to applications through the middleware. Thus all the alternative modalities were developed and tested individually over the years and became available to applications through the middleware. The same was followed for knowledge representation. A knowledge base was developed in a semantic format and querying mechanism were developed and exposed through the middleware. The coming together of the above measures made possible the development of applications in multitude programming languages (c#, ActionScript, java, python, Delphi etc.), tools (visual studio, flex builder, eclipse, mono develop etc.) and frameworks (.Net, Windows Forms, WPF, Adobe Flash etc.) that use and reuse the presented infrastructure. This for certain boosted development and productivity and allowed the facilitation of experts from various application domains and backgrounds. Using the infrastructure it was made possible even from designers to produce interactive applications with limiting programming expertise and tools knowledge.

6. Conclusions and Future Work

This chapter has presented a state of the art AmI framework for Digital Cultural Heritage. This framework has provided the building blocks to support the development of a number of application for digital cultural heritage offering novel form of information presentation, interaction and learning in CHIs. Several installations of applications were explored addressing a number of alternative topics: (a) Personalized Interaction with Artworks, (b) Mixed reality technologies, (c) Gamification techniques for education purposes, (d) Gamification as a means to produce interactive art installations and (e) portable mobile and custom hardware devices. Although these application were built on top of heterogeneous technologies, programming languages and platforms all of them facilitate the versatile framework as a provider of key enabling technologies (intercommunication, knowledge management and interaction).

Although the presented framework has been already practically exploited in the context of numerous developments and evaluated through interactive installations in public spaces, there are a number of directions where significant progress can be achieved in the future. A major research line towards this direction is the support for integrating a number of linked data end points to the knowledge layer of the framework. This will make the integration of existing data sources feasible, thus contributing to a more pluralistic representation of knowledge and the reuse of existing knowledge. Furthermore, although the interaction metaphors have been abstracted and modelled separately, the user interface currently is built ad-hoc for each interactive system instantiation. In the future it is expected that the development of a common reusable UI toolkit for interactive applications for cultural heritage will greatly boost development and significantly reduce development time. Moreover, some of the presented systems integrate some form of personalization mechanisms so as to present more focused information to each visitor. This is currently achieved at the knowledge and UI level for each application individually. In the future, it is planned to develop an information personalization layer integrated the knowledge representation, so as to store centrally user profiles and produce dynamically the required content personalization prior to the extraction of content by each interactive application. Finally, a very important path of improvement is planned through the exploitation of the log data collected in each in vivo installation. The analysis of this very rich material can provide feedback on how museum visitors interact with the system, detect problems and help redesign and improve each application as well as the framework as a whole.

Acknowledgments This work is supported by the FORTH-ICS internal RTD Programme 'Ambient Intelligence and Smart Environments' [1].

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