The versatility of augmented reality for the enhancement of cultural heritage.

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Abstract. All Virtual reality, augmented reality, mixed reality or straight-up video games can now be found in growing numbers within spaces dedicated to culture and the arts. The choice of such tools is trans-forming the traditional museum tour into a multifaceted and interactive experience to the point, in some cases, of flirting with entertainment. From our experience, the role of augmented reality hasn’t been to substitute itself to the « real » tour. On the contrary, AR invites the user to immerse themselves in an animated personal experience enriched with supplementary information. Elaborated with goals and features different from those of virtual reality, AR aims at strengthening direct contact with works of art as much as possible, inciting an active « live » use and a presence “on-site” more than “on-line”. The diversity of three logistical contexts in which we have worked — a large-scale monument, a historical palace and its heterogeneous art collection, and finally an archeological complex encompassing a traditional museum and the remains of a Roman amphitheatre — has brought us to reflect up-on the functional aspects that come to determine a personalized digital product, as tailored as possible to specific needs. Each of the three apps has permitted a deepening of each of their features in order to meet specific goals targeted by various museum institutions. In this paper we describe these features in more specific terms.

1. Introduction
The past years have witnessed a surge in the use of new technologies by numerous museum institutions, with goals of promoting and enhancing the value of cultural heritage. Virtual reality, augmented reality, mixed reality or straight-up video games can now be found in growing numbers within spaces dedicated to culture and the arts. The choice of such tools is transforming the traditional museum tour into a multifaceted and interactive experience to the point, in some cases, of flirting with entertainment.

The creation of apps aimed at a specific target — families rather than teens — combined with an effective emphasis on accessibility may significantly raise the attractiveness of historical sites and works of art that are too often understood solely by adult visitors with a good level of cultural preparedness.

However, it is fundamental in this day and age to insure that accessibility to our cultural heritage, material and immaterial, can be secured for all regardless of physical ableness or formative background. In these respects, the Information and Communication Technologies (ICT) may represent a key tool in promoting such inclusion standards in historical sites and spaces dedicated to the arts, if they are used properly. In entering the museum, the digital world can potentially bring about non negligible benefits, switching the scope of the tour by putting the attention back on the visitor and their
experiential dimension, ultimately enhancing the visitor’s overall comprehension and increasing the quantity of new data they acquire. In our opinion, in order for ICTs to prove efficient it is necessary that they demonstrate a propensity to bring the visitor and the art spaces together, bringing into museums and exhibitions the category defined as « non-public » as well. From our experience, the role of augmented reality hasn’t been to substitute itself to the « real » tour. On the contrary, AR invites the user to immerse themselves in an animated personal experience enriched with supplementary information. Elaborated with goals and features different from those of virtual reality, AR aims at strengthening direct contact with works of art as much as possible, inciting an active « live » use and a presence “on-site” more than “on-line”. The virtual elements in question do not distract the visitor from observing the cultural heritage amidst which they find themselves, they do not constitute a virtual surrogate detached from the historical and natural contexts in which said monuments, art collections and archeological sites are located. On the contrary, they enhance the tour experience, with the goal of increasing social inclusion as much as possible.

We believe that the form of technology that is used should remain discrete and as little invasive as possible, that it should first and foremost serve to promote the institution and its patrimony while presenting an entertaining, captivating quid that embarks the visitor on a journey to discover the history of art. In this respect, the insertion of elements of game into cultural contexts offers added value that feeds curiosity, particularly within a user demographic that would not spontaneously be drawn towards cultural institutions.

All above-mentioned points come together in the use of augmented reality as the main characteristic of the apps that have been developed to serve various cultural spaces in the region of Tuscany. This article describes and analyzes said points through an interpretive lens that highlights the correlation between technology, function and goal.

2. Mobile apps for the enhancement of cultural heritage

Three experiences of mobile app have been carried out in cultural heritage context:

- **MusAR** is an app launched by the National Museum of the Monumental Certosa in Calci, a splendid monastic complex founded in 1366 near Pisa. The historical legacy of the museum was the object of a regional census for surviving music sources. It thus became the protagonist of an app promoting knowledge surrounding the Certosa, its artistic treasures and the monastic community that has inhabited its walls for centuries. Augmented reality has permitted to create a route within the large spaces of the museum as it stands. Following music as its unifying thread, the experience contrasts with the sacred silence that once governed the lives of friars.

- **ArtimesisArt** is another app that promotes the dissemination of the historical and artistic identities of the city of Arezzo. Its target audience is mostly young. The premise of the app is a prize-winning game that takes children and teens inside a museum that curates a large art collection and which would otherwise prove difficult to unpack. The recreational aspect of the app is able to turn the traditional museum visit into an explorative experience through the « catching » of visual and musical works of art located alongside an itinerary.

- **ArcheoArezzo** app is dedicated to Etruscan and Roman histories. It enlivens the visit of the archeological museum of Arezzo and its stupendous amphitheatre, located in the city center. The emphasis on high accessibility and on the need to integrate pre-existing informative material and projects into a brand-new graphic and communicative fabric is what most characterizes this app which aims at learning more about the great myths of antiquity through the precious local objects displayed in the museum.

According to one classification system for areas of application of augmented reality in CH, augmented reality is mostly used to enhance the experience of the tour in museum and spaces dedicated to art, and secondly, to explore cultural heritage in real and virtual modes to discover, understand and acquire new information. Another precious feature of AR is to provide the user with the opportunity to
visualize or interact with an image that reconstructs the work or art or historical site, standing for the original. In contrast with a traditional exploring activity, the latter holds more potential since it doesn’t presuppose an in-depth knowledge of the work, thus being also accessible to users of preschool age, or more generally without a cultural background.

Starting from the above-mentioned hypotheses which effectively demonstrate the educative and didactic scopes of CH apps and the use of augmented reality to support culture, we can see what solutions may facilitate informal learning about our historic and artistic heritage in a time when while these technologies may no longer be considered new, they still hold an innovative potential.

The diversity of three logistical contexts in which we have worked — a large-scale monument, a historical palace and its heterogenous art collection, and finally an archeological complex encompassing a traditional museum and the remains of a Roman amphitheatre — has brought us to reflect upon the functional aspects that come to determine a personalized digital product, as tailored as possible to specific needs. Each of the three apps has permitted a deepening of each of their features in order to meet specific goals targeted by various museum institutions. The following pages describe these features in more specific terms.

3. Augmented reality

Augmented reality (AR) can be described as a direct or indirect view of a physical real-world environment, in real time, that has been enhanced by adding virtual, computer-generated content to it [1]. Augmented Reality contrasts with Virtual Reality (VR) in that the former adds digital information to images and real-life contexts, while the latter immerses the viewer in a digitally generated world, allowing them, for example, to fly over a city without physically taking off the ground [2]. Another technology that has been recently introduced is mixed reality, which merges the continu of augmented reality and of virtual reality in order to anchor virtual objects into the real world, instead of simply superimposing them onto it [3].

MusAR, ArtimesArt and ArcheoArezzo all use the technology of augmented reality: planar images (paintings, frescoes, etc.) and three-dimensional objects (sculptures, artifacts, relics, etc.) have been mapped and inserted into these apps as target images. Conducted experiments have confirmed initial hypotheses regarding the relationship between users and AR: the use of the latter forces the visitor to be in direct and active contact with the work of art and or/ the surrounding environment and allows them to live a subjective experience according to their own pace, knowledge and momentary sensorial impressions, especially if the technology is accessed from a personal device.

Within an app, besides triggering a surprise affect, augmented reality opens doors for curiosity to become the motor of a cognitive journey. Because it is highly versatile, AR also allows for the perceived information be adjusted to chosen context and knowledge depths, stimulating a combination of experiences, information and imaginations.

![Figure 1. MusAR App: Concerto angelico fresco.](image)

3.1. Augmented reality and music
Within this wide versatility, we decided to favor a couple of AR’s potentials: in MusAR, for example, AR allows one to «play» sheet music and depictions of musical instruments. Framing the *Concerto Angelico* fresco in the Certosa prompts the sound of the represented antique musical instruments to play. The same feature is used for the Sala capitolare fresco, despite the time and human-caused disappearance of the pictorial work. It is also possible to see its visual reconstruction while the grand-ducal orchestra shows up again, engaging in Eighteen-century concert playing. This allows the visitor to discover what an orchestra was composed of at the time, what instruments were involved and how they were played. All such information is seamlessly integrated within a coherent and real historical context.

Beyond the sole representation of musical instruments, musical iconography allows one to «see» the music while augmented reality gives voice and body to the images that are in front of them. In this way it becomes possible to involve more readily a non-specialized audience and to lead the visitor through the discovery of musical elements from museums and collections. Visitors of the Certosa may also listen to liturgical singing by opening the choir book kept in the old sacristy, or learn about the birth of musical notation by turning the pages of a sixteenth century treatise in the monks’ library.

![Figure 2. MusAR App: Reconstruction of the grand-ducal orchestra fresco.](image)

![Figure 3. MusAR App: Choral book.](image)
In ArtimeisArt this same feature has been used as a complement to the exhibition dedicated to the cantor et magister Guido d’Arezzo. This medieval monk had the opportunity to experiment with his innovative didactic musical method: Guido used the first syllables to the then-famous hymn to Saint John the Baptist to mark the heights of the sounds of a musical scale, and first introduced the use of the musical staff. Besides, he taught how the palm of the hand could be used as a mnemonic device for the intonation of the musical scale.

![Figure 4. ArtimeisArt App: Guido d’Arezzo’s portrait and Guidonian hand.](image)

With the help of ArtimeisArt, visitors of the Fraternity Palace Museum may understand the cultural importance of Arezzo in the eleventh century as well as the key role Guido Monaco played in the history of music. Framing the works in display with the app’s camera feature — the thirteen-century music-playing angels, an eleventh century mosaic, an illuminated choir book and a portrait dated from the 19th c. — allows the viewer to travel back in time to admire the old duomo atop the Pionta hill, listen to the sounds of medieval instruments and the Benedictine monks’ singing, and learn music using the technique developed by Guido d’Arezzo.
3.2. **AR and gamification**

Another feature strictly tied to the use of augmented reality as it is embedded in these apps has been gamification, or the implementing of engagement dynamics as learning tools. Gamification can be defined as the adoption of game technology and game design methods outside of the games industry [4]. The gamification approach has been successfully used in numerous museums and cultural institutions. One such case that is famous in Italy in the National Archeological Museum of Naples and the game Father and Son [5].

The ArtimeisArt app, together with the guide of the Fraternity Palace Museum, offers a game that follows children and young people in a quest for knowledge of art and history in a simple and fun way. As in famous video game *Pokemon Go*, the game consists in discovering and “catching” all sixteen works of art preserved in the rooms of the museum along the AR itinerary, the ultimate goal being to earn the diploma of Vasarian artist. The quest is pursued alongside a virtual Giorgio Vasari, a famous architect and painter at the time of the Medici. Once the works exhibited in the museum rooms have been identified, they may be framed with the device’s camera. A sound and visual effect combo signals the score-tracking progress. After reading or listening to a concise information sheet complete with images, the user may move on to the next stage until they reach the final score, which entitles them to a diploma in both digital and paper forms. Easy and intuitive, the game was designed to increase the presence of families within the museum. Its rather simple competitive concept, combined with the surprise effect it generates, make it entertaining to mostly children and young people, but adults will appreciate it just as much since it traces an essential path within a vast collection, highlighting the main works, events and important characters that make up the history of Arezzo.
The same dynamic is exploited in ArcheoArezzo, where augmented reality becomes a device for «catching» and identifying twenty historical finds that tell as many stories of heroes, men and gods from antiquity. During the visit of the museum, classical culture is known through the observation of the depictions and decorations of vases, bas-reliefs, sculptures, mosaics, and objects of common use found in the archaeological sites of the Arezzo area. In both apps, the information sheets that appear once the work of art has been framed set on the audio mode: actors’ voices interpret the text, enhancing the involvement of visitors, young and older. With ArcheArezzo our goal was to give more prominence to the storytelling aspect by producing stories in which the characters - Hercules, the Amazons, Penelope, the Sphinx, Romulus and Remus and many others - speak in the first person, narrating their stories, loves and pains.

In MusAR, the playful aspect has been overlooked, favouring the classic cognitive aspect, with only the historical and artistic textual information sheets present. However, we wanted to graphically represent a typical day in the life of monks, with its alternation of community life and hermitic moments, by placing small silhouettes in the various rooms of the Certosa: using a virtual clock, one can see these small white figures moving into the church for the prayers of praise and vespers, gathering in the refectory for the celebratory lunch, retreat to their cells, the library or the vegetable garden for their daily work. The app offers a simple and direct way to visualize the peculiar relationship between architecture and spirituality that exists in the Charter houses around the world.

4. Mapping features

Another central element of the three Tuscan apps is the presence of a map of the cultural sites to which they are dedicated, and of an indoor geolocation system based on BLE (Bluetooth Low Energy) technology that allows the visitor, through devices called beacons positioned in strategic points of the itinerary, to know their location inside the museum. These two elements of geographical description, closely related to each other, allow to develop some interesting functionalities in cultural dissemination.

A navigable and searchable floor plan, with elements connected to multimedia content, presents the first key information about the place one is about to discover; through it, one gains an overview as
well as data useful to the organization of the visit such as the space’s size, the average time to be spent on said visit, and the physical accessibility to the space in question.

Figure 7. ArcheoArezzo App: map and archive sections.

The generated maps also contain the itinerary that visitors can choose to follow inside the museum. In this sense they are “a guide within a guide” since they offer a practical common thread to better understand the peculiarities of the cultural heritage that is kept/curated. The thread in question may be a thematic route, as is the case for the Certosa in Calci, where music leads the exploration of monastic spaces. It could also be a selection of works that become stages for storytelling, regarding the cultural history of Arezzo, or the Etruscan and Roman myths and legends in the cases of ArteMISArt and ArcheoArezzo, respectively. In these two above-mentioned experiences, the map also becomes a functional tool for the game: thanks to it and in combination with the geolocalisation system, the user orientates themselves inside the museum with the goal of identifying the artworks that have to be “caught.” This is done thanks to the presence of beacons: entering a room or approaching a point of interest are thus visually indicated on the map, determining one’s position in real time. The feeling of being “present” within a space is considered an important element in the dynamics of user involvement during the tour experience, which can be strengthened thanks to the technological component.

Dynamic maps can also be useful to visualize several overlapping layers of information: in ArcheoArezzo this feature has proven essential to the integration of more thematical itineraries inside the museum. Through a legend it is possible to select only the AR itinerary (with the game), rather than the Gatto Gaio’s game dedicated to children, or #ZICH, which introduces us to the fascinating history of Etruscan writing. In this way, the user may choose the cognitive itinerary most adapted to their standards through a single access channel, with the possibility of mixing up and repeating the visit several times, thus discovering the cultural heritage from various points of view.
5. Accessibility

Although the topic of museum accessibility has long been debated in the scientific field with fruitful and useful reflections, many critical issues still remain before we reach a point of systematic interventions. MusAR, ArtimeisArt and ArcheoArezzo were not created with the primary goal of facilitating accessibility to museum institutions, but rather of making a small contribution to the dissemination of culture and the spread of ICT across the regional territory. Despite this, the work carried out has led to a virtuous confrontation with the UICI (Italian Union for the Blind and Visually Impaired) who has made itself the spokesperson for some requests for modifications and implementations, but also and above all, who has shown that it is possible to help people with vision problems also through including small details and attentions in the creation of a digital product. For example, the insertion of actor-interpreted textual content in ArtimeisArt, which initially had the primary function of involving a younger audience more easily, has proven to be of great help also for the visually impaired user. This simple functionality has allowed one to remedy to signs that are too small, reduced lighting, and has managed the inclusion of a larger user target into an entertaining enjoyment of the museum. In this sense, the bilingual function, selectable at any moment during the visit, is another feature that is in support of social inclusion since it allows access to the artistic heritage of Arezzo even to a foreign audience, which has always been present in our territory, thus bringing the Italian cultural offer to an international level.

The concept of accessibility must also be apprehended from an economical angle: the possibility of having a free app on one’s own device surely encourages tourists, most importantly those who travel with family, to enter museums and linger further into the knowledge aspect of their visit at no additional cost to this of the entrance fee. In this sense, being able to download the app privately before heading to the museum in order to have more information to test one’s interest for the collection and better organize a visit is also key; this same functionality, enriched with all the contents acquired using augmented reality, is also useful afterwards because the content can be used in offline...
mode. One should consider the educational potential of such a feature, or even simply the pleasure of sharing this experience by sending images and texts via one’s smartphone.

6. Technology
ArtimeisArt is an Android and iOS application developed using the Unity3D graphics engine, one of the world's leading platform for the creation of playful and interactive applications. Unity3D is a cross-platform graphic engine with which it is possible to carry out game development, animations, 3d experience and educational software. Unity3d supports PhysX physics engines, particle system and virtual and augmented reality features [6]. Furthermore, it includes a Rendering engine supporting Direct3D, OpenGL and other proprietary software as well as processing and post-processing real time tools (such as light mapping) [7].

From a technical standpoint, the library that allows the object recognition is represented by EasyAR, an SDK (software development kit) developed by VisionStar Information Technology. Through the use of EasyAR it is possible to create applications capable of recognizing two-dimensional images and three-dimensional objects through their natural features, i.e. colour pattern, texture and geometrical shape of the object itself.

The recognition event can be associated with a series of interactive contents, images, videos or animations and audio files that contribute to creating a reality "enriched" and integrated with the environment in which the object or works of art are contained. In the case of ArtimeisArt, the recognition event is linked to a visual effect followed by an increase in the game's score: once the maximum score is reached, another graphic and sound effect combo precedes the appearance of an image corresponding to the virtual diploma that marks the end of the game.

Another important feature included within ArtimeisArt is related to indoor geolocation. Small devices called Beacons - low energy emitters that communicate via Bluetooth low energy protocol (BLE) -, have been placed in the rooms that are part of the exploration itinerary. The traditional Bluetooth requires a significantly long scanning time (~ 10 s), which limits its value for localization. However, the new BLE Bluetooth protocol, supported by most current smart devices, has overcome the limitations of long scanning time. Moreover, the BLE beacons have the following advantages: power saving, small size, light weight and low cost [8]. For this reason, BLE technology is becoming a standard for sectors such as indoor positioning or proximity marketing. The signal emitted is received by the device that is running the app: an algorithm for comparing the signal strength "chooses" which beacons is closest by "turning on" the corresponding room: in this way the user knows their real-time position.

7. Conclusion
The possibilities that AR holds are manyfold and the apps dedicated to cultural heritage may come in all shapes and sizes. Beyond the possibility that AR offers to enhance elements, Ronald T. Azuma for example, stresses its potential to « remove » said elements from our visual reality in order to focus one’s attention solely on what interests them. Stripping the visual aspect off a painting, a monument or a landscape view in order to bring only essential information to light may be of use to communication down the road.

As far as the management of ICTs’ audio components is concerned, which has already been experimented with satisfying results, putting real and virtual environments in dialog via hearing could be interesting. We would like to power the user’s involvement by using earplugs for a surround sound experience, by inserting personalized audio elements into the AR recognition routine of the images and/ or amplifying the sound of the environment in which the visitor is located. Enriching the visit with sounds and noises may help the visitor improve their knowledge of the environment in which they find themselves: hearing litanies and prayers while framing a church fresco, excerpts from recitations in an ancient theatre, or the buzzing sound of street life amidst the remains of an imperial forum would turn the visit into an immersive experience.

Another aspect to explore is the application of augmented reality to an outdoor environment, that is to say, extending the use of cultural apps created for individual museums to entire urban areas. By associating outdoor geolocation with information on directions and buildings, tourists could get help in
orienting themselves but most importantly, in learning historical and artistic information about their surroundings in real time. This way, the entire historic centre for example may become an open-air museum, within which it becomes possible to trace one or more cognitive paths that tell the historical value of local architecture for example, or of a theme proper to that specific territory, say ceramics rather than music and how it’s developed and been defined over time. AR facilitates the anchoring of past events — may they be battles, tournaments, fairs or markets — in specific sites and landscapes, prompting the visitor to contextualize in a simple and immediate way what can be read in books; presence, *hic et nunc*, can be an optimal catalyst for the start of a cognitive process that is within everyone’s reach. For a moment, we may be a part of that event and thus imagine it more easily as it materializes before our eyes thanks to the support of a few graphic and sound effects that « enhance » our perception of the place as it once was.

To conclude, the experiment carried out in the field of technologies applied to CH has allowed us to verify on site the potential and crucial nature of these apps. If on the one hand, the richness of historic and artistic heritage stimulates the production of new products that will become increasingly easy to use and faster in their delivering information. On the other hand, the real ability to involve and trigger a cognitive process is closely linked to the way it is communicated. Texts, images and multimedia content should be able to condense a vast and complex cultural background stemming from the research and professionalism of experts. ICTs are therefore essential to the process of reaching different user demographics and disseminating knowledge to them without trivializing it, regardless of what type of digital technology is used.

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