SensiMAR – Designing a Multisensory AR System

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***Abstract*— To deliver more intense and enhanced experiences, multisensory applications have the goal to stimulate all our senses. The way these multisensory systems have been implemented is very distinct, since there are a lot of different approaches among them, aiming different goals. Thus, the structure defined for these systems depends on the stimuli that are being exploited, the technologies that are being used, the context in which they are being implemented, and on what is intended to obtain with the system. This study aims to propose the design of a multisensory system, named SensiMAR, that will provide an outdoor multisensory AR experience located at a cultural heritage site, allowing users to perceive different levels of immersion with the addition of a spatialized soundscape and with related smells.**

Keywords*— *Multisensory, AR, Cultural Heritage, System Design

I. Introduction

Cultural heritage (CH) has been one of the many fields where technology has been increasingly used to improve the visitor's experience. Looking forward to engaging their visitors when exploring their spaces, and aiming to provide enhanced experiences, CH entities have been appealing to new technologies for the last decades to attract more visitants. One of these technologies that has seen an increased rate of adoption in these places, is augmented reality (AR), due to its ability to provide virtual experiences while also being aware of the surrounding reality. This feature, which differentiates from virtual reality (VR) solutions, appears to be a great advantage to use among CH sites, since, to fully take benefit of the experience, it must be enjoyed *in-situ*. Despite its early appearance during the 60's [1], it was among the last decades, following the advances in mobile computing, that AR has become more popular acquiring some prominence. Recent mobile AR applications, where a mobile device can be used to experience AR *in loco*, has provided wide flexibility for developers to increasingly appeal for this technology amid different areas, including CH.

Among the diverse mobile AR solutions proposed and implemented in CH contexts, such as in urban heritage in Dublin, Ireland [2]; in Travel Guides like in Corfu, Greece [3], or in Brno, Czech Republic [4]; in museums, as in Deoksugung Palace, South Korea [5], or in Cornwall, UK [6]; or for outdoors such as in Knossos, Greece [7], or in Conimbriga, Portugal [8]; the conducted researches reveal good feedback from the users' point of view, being recognized as an excellent solution to use with a positive impact in their perspective [9].

Since the results coming from these experiences are very positive, AR is projected as a technology to have high chances to be one of the most engaging experiences, regarding the use of technology in CH. However, its implementation can raise several challenges, a window of opportunity that triggered the creation of an ambitious application called SensiMAR, which aims to offer a multisensory AR experience.

Following the test and evaluation of an AR application used in a cultural heritage site [8], this new system will be developed to better fulfil the expectations of visitors from CH sites. Accordingly, and after an acceptance study carried out to better perceive the behavioural intention to use AR in archaeological sites [10], an AR app will be developed, to present more information to users, namely, an archaeological site in ruins, including the addition of virtual architectural structures, avatars, animated characters, diegetic sounds, and smells.

The current study aims to outline and design a multisensory AR system, which could provide the knowledge to better understand if cultural heritage visits can be enhanced by having access to multisensory AR experiences *in-situ*. To accomplish this commitment, evaluating the sense of presence of participants from an AR experience throughout multisensorial stimuli, among their visit to a cultural heritage outdoor space, will be the focus for this research.

Given the small amount of studies related to smell experiences associated with AR technology [11], a hypothesis which states that several stimuli in AR applications can be explored to enhance experiences in cultural heritage, is raised. Intending to verify this premise, with the SensiMAR app, the following hypotheses will be tested:

H1. The use of several stimuli in an AR application during a visit to an archaeological site will lead to a better sense of presence when compared to a regular visit.

H2. The use of several stimuli in an AR application during a visit to an archaeological site will enhance the visitors' experience.

H2. A. - Because they will get more information about the site.

H2. B. - Because they will feel more involved in the experience.

H2. C. - Because they will be more satisfied with the overall experience.

H3. The use of several stimuli in an AR application during a visit to an archaeological site will lead to a more enhanced experience when compared to a virtual reality experience.

Therefore, in order to collect accurate data to successfully understand how to enhance experiences using AR approaches in CH, a design of SensiMAR application is established.

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II. Previous Multisensory Applications in CH

When developing a technological solution to enhance visitors' experiences while visiting a cultural heritage site, such as an archaeological site, institutions aim to offer a product that will please visitors, eager to make their experiences more interactive, positive and memorable. Literature gives us several examples of experiences that successfully achieved this purpose, proving the added value of using multisensory experiences.

A. Multisensory Applications in CH

Given the recent literature available, multisensory has becoming an appealing solution for museums, archaeological sites, tourism spaces, and other CH places.

This search reveal that the more common multisensory applications are indoor and based on VR, such as the Vulci Archaeological Park Museum in Italy [12], the Virtual Experience of Tanning in Medieval Coventry [13], the Digital exploitation of artefacts in the National Archaeological Museum of Marche [14] or the Interaction with ancient Egyptian sculptures [15]. Despite the mandatory allusion to VR when introducing AR, following the concept of *Virtuality Continuum*, whereas the user is totally immersed in a virtual environment when using VR, the experience with augmented reality allows the user to be aware of both environments: virtual and real [16].

Regarding AR experiences, some interesting installations alluding to multisensory experiences are found, such as the "Multisensory Art Gallery", at the Tate Britain art gallery in London [17], the "Refugi 307" bomb shelter, from the Spanish Civil War [18] or the mobile multisensory AR project M5SAR in Faro, Portugal [19]. According to a scope of multisensory experiences in CH, despite the little amount of multisensory AR applications found, in particularly with user tests, the combination among AR and immersion is stated as an appropriate case study [11].

The given studies allow affirming that olfactory stimulus is an essential sense to help users to recall for memories and to get an enhanced experience. The visual information, the most common approach among CH sites, has a significant role in the engagement perceived by the user. The use of sound, especially if it relates to object sounds and delivered in a 3D space, also presents benefits for the users' perception [11].

B. Designing Multisensory Apps

According to a literature review, that aimed to notice multisensory applications for CH, the use of screens or monitors was the most common device used for visual stimulus. These devices were used in The Haptic Museum [20], in The Fire and the Mountain [21], in The Gold Museum in Bogotá [22], in the Museu3I [23] or in the National Archaeological Museum of Marche [14]. CAVE systems (a small room where at least three walls act as huge screens) and HMD (head-mounted display) devices also emerged, such as in Museum of Pure-Form [24], the CREATE project [25], and in the Gion Festival in Kyoto [26], using CAVES; and The Feelies [27], the Interactive Haptic System for Archery [28] or the Tanning in Medieval Coventry [13], using HMDs. We may notice that the Zelige Door on Golborne Road was the only study detected, so far, which has used a mobile device for providing visual exploration in a multisensory application in CH [29].

For audio delivery, speakers were the most common device used for this type of applications, being noticed in cases such as The Museum of Pure-Form [24], the CREATE project [25], the Gion Festival in Kyoto [26], or the in the Gold Museum in Bogotá [22]. Experiences which aimed to provide a more individual experience, such as the Tate Sensorium [17], or The Feelies [27], used headphones for the audio experience.

When diffusing smell, the few examples detected, presented olfactory displays developed by their own, as found in The Emotion Organ[30] or the Zelige Door on Golborne Road [29]; used perfumes, which was the case of the Tate Sensorium [17] and The Feelies [27]; or, in a more technological approach, a Computational Fluid Dynamic (CFD), which was the case of the Tanning in Medieval Coventry [13].

Haptic sensations are being provided through the use of haptic interfaces, like the Gion Festival in Kyoto [26], the Gold Museum in Bogotá [22], the Museu3I[23], the Tate Sensorium [17]; or, as the case presented in The Feelies [27], and the tanning in Medieval Coventry, which used fans (for wind) and a heater (for temperature).

III. Multisensory AR System Description

This section will characterise a broad system proposal for an outdoor multisensory AR application to be implemented in a CH site.

A. Multisensory AR for CH: Functional Perspective

From a functional perspective, an implementation of a multisensory AR system for CH contexts should provide to the user, when exploring a given site in ruins, the ability to perceive in real-time relevant virtual elements that complement the structures or objects which were damaged or destroyed due to natural or political causes. These added elements can include visual elements, audio clues, or other sensory data, that helps the user to understand better and perceive the place when it was inhabited. The proposal of the current research intends to add into the real scenario three stimuli, namely, sight, hearing and smell.

The images provided, that complement the current place, should be presented at its original place, at the correct position and scale, to provide an accurate and realistic perception of the ancient scenario. Also, as a visual stimulus, animations that include virtual humans should be used – avatars – in order to better engage the user in this mixed reality scenario, aiming to assist the immersion and complete the overall experience [31].

The soundscape of the scene must be in a 3D scene, in such manner to give the user the sensation that the sounds are coming from different directions and various distances, therefore providing a spatialized soundscape which is more engaging and realistic. These sounds should recreate the soundscape of the ancient times, when the ancient city was in activity.

The smells should be added to the augmented scenario at specific moments, depending on the timeline of the experience. In order to provide a relevant experience, the smells should be released in the vicinity of the user.

All added elements at a given CH place must be accurate and historically correct. Thus, all data must be validated by the archaeological responsible of each CH space.

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Figure 1 illustrates what the multisensory AR system should provide to the user, when implemented in a CH context, specifically, an archaeological site.

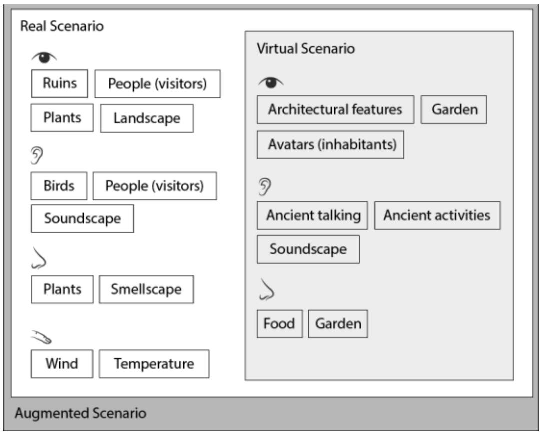

Figure 1 – Illustration of what the augmented scenario of a multisensory AR system should provide to the user, considering the real and the virtual elements.

The multisensory experience should be able to blend all information of the presented augmented scenario, with real and virtual elements. Thus, experiencing this system allows the user to view the current ruins in place, to listen to the real soundscape, which includes birds, people that may be walking around and talking, sensing the surrounding ambient smell that can include plants, feeling the wind, the weather and all the other natural elements.

B. Multisensory AR for CH: Non-Functional Perspective

A multisensory AR system such as the proposed in the current work, considering the case study of the Roman Ruins of Conimbriga, given the wide-ranging target group of users, must be user-friendly. As literature suggests, to build a simplistic user interface is essential, having the minimum stages as possible, in order to allow users to find it intuitive and engaging in order to successfully experiencing the system [32].

The added stimuli that will be explored among this experience are sight, hearing, and smell. For each stimulus exploited in this multisensory AR system, this section presents an overview of how they should be implemented and how they must operate.

Figure 2 illustrates a general overview of the multisensory AR system operability.

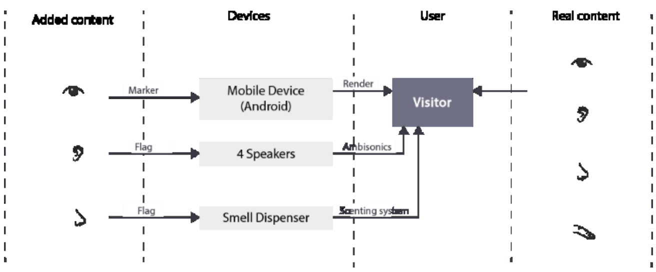

Figure 2 – Overview of the Multisensory AR system.

The added content, corresponding to visual, audio, and smell stimuli, requires specific equipment. The visual content will be accessible through a mobile device (such as a smartphone or a tablet). The experience will be triggered by a marker located in a specific place from where the visitor will be able to perceive a correct visualisation of the virtual content of the experience over the real scenario. Sound and smell will be triggered by a flag, meaning that the system will send a signal at specific moments, in order to activate these stimuli. Sound will be played using speakers installed *in-situ*, placed in a circle around the user to better profit from the Ambisonics technique (described further bellow), and smell will be spread through a smell dispenser.

Figure 3 illustrates the architecture for the multisensory AR system, and how different elements should connect with each other.

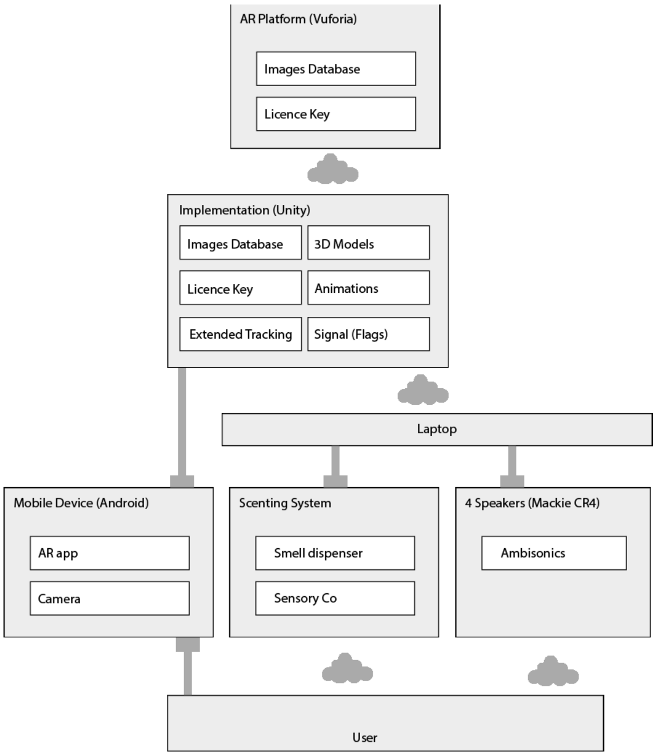

Figure 3 – Architecture of a Multisensory AR system, for mobile AR, when adding stimuli to engage sight, hearing, and smell.

This multisensory system is mainly built using the Unity 3D[1] platform. The integrated Vuforia SDK[2] will be used to implement the AR application for mobile devices. The communication between the Vuforia portal and the app developed in Unity will be wireless and, once installed in the mobile devices, no wi-fi connection is needed.

The app, running on a smartphone, will be responsible to trigger the other two stimuli which are included in this multisensory experience: hearing and smell. Through a local network, the signals will be received by a laptop that will start the audio experience – and send the output to the speakers – and start the smell dispenser – releasing the aromas.

The user, carrying only a smartphone or a tablet in their hand, will be exposed to all three senses of this multisensory experience, in addition to the natural five stimuli coming from the surrounding environment.

[1] More information about Unity 3D on www.unity3d.com.

[2] More information about Vuforia SDK on www.developer.vuforia.com.

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1) Image

For this multisensory AR system *in-situ*, a mobile device should be used to provide the visual experience. A smartphone or a tablet can be used. The system that is being developed is suitable for any Android device starting from Android 4.0.3 (Ice Cream Sandwich), as it does not require a high-performance processor or GPU.

Vuforia SDK will be used along with Unity 3D to create the AR app, using markers for recognition and tracking of the experience. According to literature that considered frameworks and techniques for implementing AR for outdoors in CH contexts [8], [33]–[35], Vuforia appears to have good results while performing the experience, being confirmed by users' opinions. system is mainly built using the Unity 3D platform. Several images will be uploaded to the Vuforia database to be used as markers. Also, to validate and make the app available for usage, the licence key will be applied to the AR camera when developing the AR app

The user experience should be straight forward, with a minimalistic user interface to navigate in the system. Handling the mobile device, the user should be notified to point the camera of the device to a given spot, where the system will automatically recognize the marker and will present the virtual elements that will augment the scenario, accurately aligned over the nearby ruins. As the user discover the surroundings in 360 degrees, the *Extended Tracking* (a tracking feature of the Vuforia SDK based on natural features) will allow the user to keep exploring the virtual elements over the real scene, without losing track of the marker that may get out of the field of view of the mobile device camera. Figure 4 resumes the AR process.

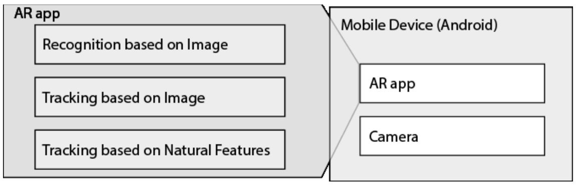

Figure 4 – Summary of AR process in the mobile device.

The camera of the mobile device is used for several purposes: recognising the markers and collecting the images used for the recognition and the tracking, but also to allow the superimposition of the virtual elements into the real environment – the real elements that are not being occluded by the virtual content.

Being an outdoor experience, some factors may interfere with the quality of this experience, such as the sun, which has been pointed out as a factor that may hamper the experience. It is also important to keep aware when implementing and testing an experience of this kind, the area surroundings should not be very crowded to avoid intermission of people on the markers used by the AR experience. Another issue that may appear during users' experiences is related to the tracking based on natural features. For a good *Extended Tracking,* it is required to explore the surroundings slowly in order to keep the virtual position accurate to the real scene. Even advising participants for moving the mobile slowly, the speed of exploring the environment depends on each user's will and perception of movement (ability to detect if they are going too fast or not, by observing the virtual positioning when exploring), which might lead to less accurate overlapping experiences for less skilled users.

2) Sound

Aiming to present a full and endless sphere of sound, without being restricted by the limitations of any specific playback system, as part of the environment where the experience takes place, the sound system should be implemented *in-situ*, using speakers.

Diegetic sounds, whose source are related to the actions that were performed in the ancient times for that given spot, will complement the soundscape available of the experience.

Ambisonics, a method for recording, mixing and playing back three-dimensional 360-degree audio, will be used. Despite its early appearance in the 1970s, the system was not commercially adopted until recently with the development of the VR industry which requires 360° audio solutions [36], as recently proposed in [37].

The sphere of sounds that will be created, will allow simulating a better 3D scene of sounds, regarding the distance and orientation towards the user's position. The use of speakers aims to enhance the mixture of the added sounds with the sounds that may be present in the real scene. Therefore, the perception of the sound will be more natural for the user since, in the real world, sound is directional and is heard outside the head, unlike what happens to the use of, e.g., headphones [38].

Based on the most popular Ambisonics format, the B-format, the audio system for SensiMAR prototype proposes four channels to reproduce a complete sphere of sound (a quadraphonic system). Four speakers will be installed in place to provide all these added sounds. A loop track will be playing all the time, a new track will be played as the action from the sight stimulus also starts. The digital audio workstation Reaper[3] will be used for creating the playlists and to distribute the sound positioning in the sphere of sounds. Max/MSP/Jitter [4] will be used to play the soundscape continuously and to play the sound experience synchronized with the action.

As an outdoor experience, testing before the final implementation is important in order to ensure that the user will accurately receive the sound levels. Also, it is important to keep in mind that the real soundscape may change among users, since the environment may become more or less noisy, depending on the number of visitors surrounding, the activities that may take place – e.g. the fountains in another house, called House of the Fountains, that became quite noisy when working – or even the weather – the wind may hide some lower sounds.

3) Smell

Adding smell to this augmented environment will be achieved by releasing a small amount of the required smell near the user's position.

The addition of smells for this multisensory AR experience will be limited to a few smells. Although it may not be possible to create the full complexity of a specific smell, the literature suggests that is not necessary, because the human nose (for non-experts) is quite poor at determining exact smell composition or concentrations [39]. Thus, the smells that will

[3] More info at www.reaper.fm

[4] Also known as MAX, Max/MSP/Jitter is tool for working with audio, visual media, and physical computing. More info at www.cycling74.com.

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be added to the scene, are chosen in order to correspond to specific moments that will contain a strong scent associated with an element in that action.

The added smells are acquired from *SensoryCo*[5] and will be delivered using a smell dispenser, that will be placed in the scenario, having a hose close to the spot where the user is exploring the augmented scene.

Odour, is known in literature for being the most complex and challenging human sense [40], it is important to take into consideration that the way we perceive the odour of something can be affected by, among others, the temperature of the environment and by the individual's mood [41]. Considering this outdoors experience, where the temperature is not a controlled variable, neither is the wind, implementation should consider these factors in order to deliver the scents for the experience successfully. When testing this stimulus, literature highlight the importance that individual characteristics may have in results, such as the age, smoking habits, drinking habits, gender, nasal allergies, or colds [42], [43].

C. System Evaluation - methodology

Looking forward to understanding how do enhanced experiences vary along with the different added stimuli when using AR, in a cultural heritage visit, the developed system should be tested and evaluated *in-situ* by visitors.

The first stage of the testing and evaluation process is to test the multisensory AR app at an archaeological site. This experiment will take place in the ancient Roman city of Conimbriga (Portugal), whose ruins are part of the Monographic Museum of Conimbriga-National Museum.

These participants, with an expectation of 90 individuals, will be visitors that will accept the invitation to be part of this study. The scenarios that will be tested, through a between-subjects design, are: 1) no addition of data – a regular visit with no augmentation; 2) visual content, solo; 3) audio content, solo; 4) olfactory content, solo; 5) visual content combined with audio content; 6) visual content combined with olfactory content; 7) audio content combined with olfactory content; and 8) the three available senses – visual, audio and olfactory content; 7) audio content combined with olfactory content; and 8) the three available senses – visual, audio and olfactory content. Several pilot-tests will be accomplished before the user tests. By changing the levels of immersion, it is intended to infer how visitors perceive their experience towards an CH site.

The second stage of this evaluation includes the comparison of the results of this multisensory AR system *in loco*, with a VR experience, using an HMD. The purpose of this evaluation is to compare the sense of presence between these two technologies – AR and VR. Participants, with an expectation of 20, will be volunteers that will accept the invitation at the MASSIVE lab, in UTAD (Vila Real).

The estimated duration for each experience, that should be performed individually, is up to five minutes. Presential questionnaires will be used to evaluate the four factors that are stated as a robust and reliable measure of presence that can be used with confidence by researchers [44], namely, 1) involvement, 2) sensory fidelity, 3) immersion, and 4) interface quality. These results will provide data that will allow the validation of hypotheses H1 and H3, as well as, data to connect these variables to the enhancement of the visits, aiming to validate the hypothesis H2.

IV. SensiMAR Prototype Content

SensiMAR is a prototype which intends to test and validate a multisensory AR application for an archaeological site. The current section will provide more detailed information regarding the experience, that will take place in the Roman Ruins of Conimbriga (Portugal).

A. Real Scenario

The experience will occur in the remains of a wealthy Roman house, a *domus* – named Cantaber. According to its architecture and position in the ancient city, this building is the most suitable for a multisensory experience mainly due to the following factors:

- In the hall of the house, it is possible to observe details from inside the house – e.g. an interior garden known as peristyle –, as well as the main street. This allows the user to perceive information related to both scenes;
- The architecture of the house allows us to place avatars walking around since the rooms close to the user were used to welcome guests, thus allowing to easily create a realistic event with inhabitants (avatars), keeping historical data accurate.

This house had a central position in the ancient city, as it can be observed in the city map (Figure 5).

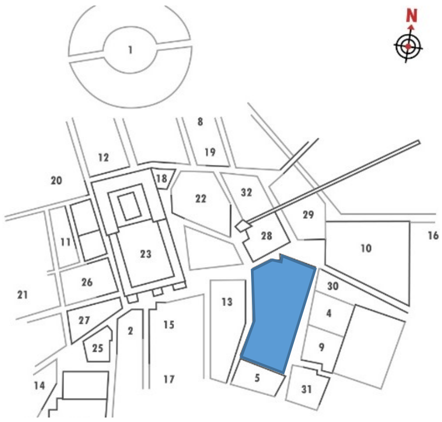

Figure 5 – House of Cantaber highlighted in the city map of Conimbriga (created by Anabela Marto, based on the map in www.conimbriga.pt).

The house of Cantaber is a big and wealthy house which has occupied a very central position regarding the urban area of Conimbriga [45].

A footprint of this Roman house is presented in Figure 6.

[5] *SensoryCo.* provides scenting and other atmospheric special effects for immersive scenarios. More info at www.sensoryco.com.

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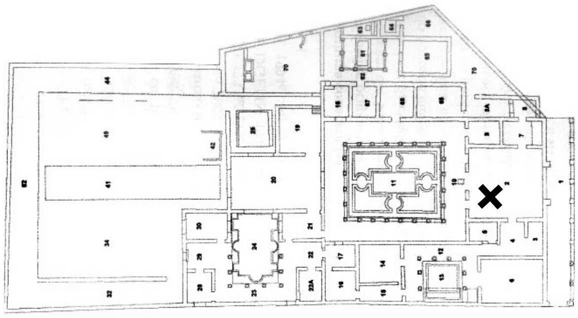

Figure 6 – Footprint of the house of Cantaber, with the identification of the user's position for the multisensory AR experience in the Ruins of Conimbriga.

The cross highlights the spot where the experience takes place. The virtual elements added, including the animations, will occur in the nearby rooms.

This archaeological site, since it was abandoned during the medieval age and it was inhabited between centuries IX B.C. and A.D. VII-VIII [27], is a quiet place today, mainly composed by natural elements.

A 360-degree picture of the real scenario is available to see at https://roundme.com/tour/445106/view/1531953/.

B. Virtual Scenario

When user points the mobile device camera to the marker available on the site, the experience will start. The images are overlapped through the mobile device screen and the sound starts playing, through the speakers. The smell scent is also activated and, depending on the stage of the experience, these stimuli will be exploited.

There are two experiences to be explored on the given spot. The first one provides visual data corresponding to the scenario and the soundscape that should characterise the scene. It means that users, at a given spot, will be able to observe the real scene and, with a mobile device, they will observe overlapped virtual elements, that help them to perceive how the space used to look like. For this first experience, the user will perceive a virtual reconstruction of the peristyle (the interior garden), with its correspondent fountains and the Ionic columns.

The virtual reconstruction also includes some rooms near the user, namely, rooms 1, 2, 4, and 7 (numbering from Figure 6).

At the same time, they will listen the sounds, due to the speakers located in that spot, providing the soundscape of that spot. For this first experiment, one smell of flowers is provided. The intensity of the provided smell, since this system is going to operate outdoors, will be adjusted considering the temperature and the wind of that day.

The second experiment includes an animation related to the place where the experience is happening. Avatars (inhabitants from the Roman Era) appear from one room, chat with each other and will interact with a third avatar that is going to appear outside, in the road. This second experiment adds new sounds and a new aroma (smell of fish), matching with the visual experience.

1) A Storyboard for the Augmented Scenario

For the first experiment, the action happens in a loop, where the provided images are static and the soundscape is a five minutes track playing in loop. The smell will be dispensed at regular periods of time.

Figure 7 depicts the scenario for this first experiment, identifying the positions of the elements that should be augmented.

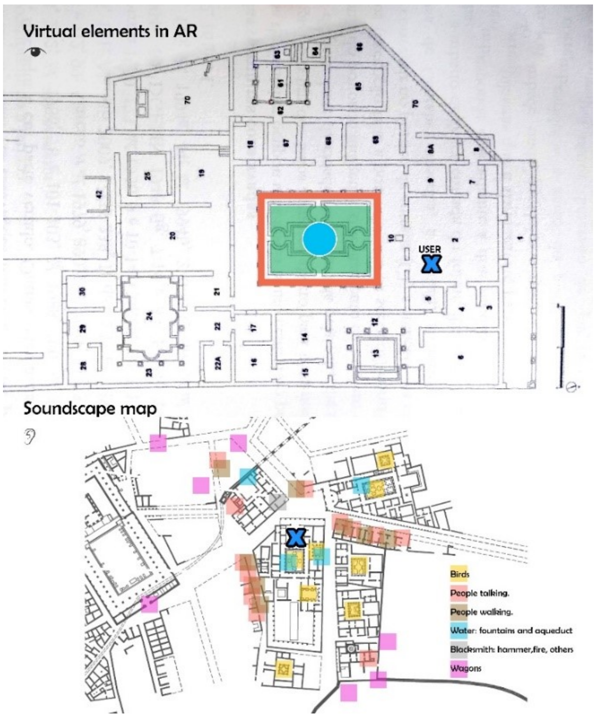

Figure 7 – Representation of the maps corresponding to the first experiment. On the top, the virtual elements that will be added with the AR experience. On the bottom, a sound map regarding the sounds that will constitute the soundscape.

For the second experiment, when an animation is triggered, an accurate interaction among the different senses is needed. For this matter, the created storyboard, with a total of 6 scenes) is the key to integrate all stimuli at the right moments. An example is illustrated in Figure 8, with scene 2.

This scene, that will occur 10 seconds after the experience started, will last for 20 seconds and is named "Romans appear". Here, two Romans (avatars) walking and talking, appear from room 4, and go to the vestibule. In the soundscape map, apart from the ambient soundscape playing in a loop (following with the first experiment), the two romans talking in Latin is the more obvious sound of the soundscape. Withal, the user will listen the steps of the romans and three wagons riding having one getting closer (wagon A).

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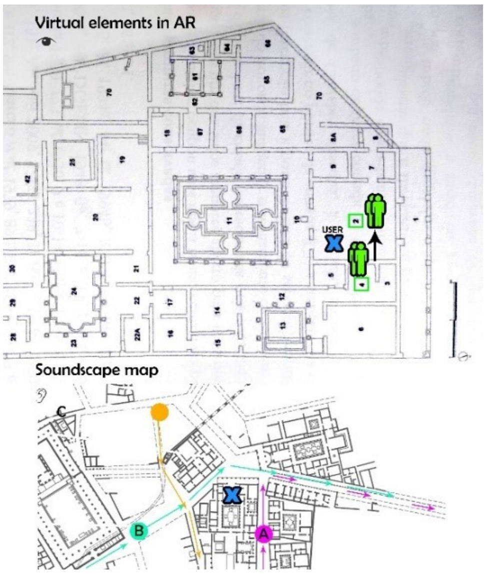

Figure 8 – Scene 2 [0'10'' – 0'30''] "Romans appear". Two romans walk and talk Latin until they stop in vestibule, looking outside.

These sounds are also depicted in a perspective view of this scenario, illustrated in Figure 9.

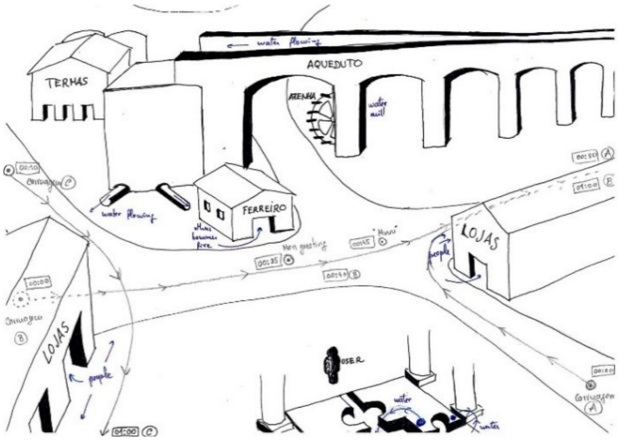

Figure 9 – Perspective view of the sound sources for the second experiment.

The perspective view of the sound sources presented in Figure 9 is used to better define the position and orientation of each one at a given moment.

V. Conclusion

SensiMAR is a multisensory AR prototype to be used in cultural heritage sites, designed to be implemented in outdoor contexts, such as archaeological sites.

Integrating different stimuli in a CH visit, while exploring the real scenario, is considered by the literature an excellent tool for a natural and strong sense of presence for users. In order to not alienate users from the real scenario, the added elements should be carefully designed and planned.

This study presented relevant topics regarding the amount and type of information to be added to the experience, aiming for a balanced and natural augmented scenario. The visual elements should not hamper the real perception of the space, thus the elements to be added in the scenario must be at a certain distance – not too close to the user – and must be relevant, in a manner that their presence in the experience, will provide useful and engaging information for the user.

The added soundscape – overlapped on the natural soundscape already present –, with diegetic sounds to enhance the involvement of the user into the augmented scenario, can also have sounds that are out of the field of view. This intends to search for a natural process of how we perceive sound in the world, where some sounds must be triggered according to the action performed in the visual data.

The smell, the more complex sense to deal with, should be carefully used, since a natural smellscape will also be present. From a softer smell to a stronger one, this system was designed to better perceive how scents can influence AR experiences.

A multisensory AR system such as SensiMAR is ambitious in the sense of integrating several stimuli, such as, the smell in an outdoor environment. Very little research was found for designing and for evaluating this type of solutions and, thus, the knowledge gap concerning to multisensory AR applications, emphasizes the need for research and implementation should be accomplished by testing and evaluate multisensory systems for visits in CH sites from the users' perspective.

A deep literature research must be accomplished in this field to attain a solid and reliable solution when implementing multisensory AR in cultural heritage. For immediate future research, it is proposed the implementation of this system, testing and evaluating the proposed variables, to solidify its strength in future implementations, as well as to validate a reliable evaluation methodology for multisensory AR systems.

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