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Internet of Things prototyping for cultural heritage dissemination

Imran Khan, Ana Melro, Lídia Oliveira, Ana Carla Amaro
Dept. of Communication and Art, University of Aveiro, Portugal
Imran10111@ua.pt, anamelro@ua.pt, lidia@ua.pt, aamaro@ua.pt

Abstract

Internet of Things is an emerging technology that is presently revolutionizing the worldly pursuits. The evolution of mobile equipment has pioneered IoT as state-of-the-art technology in the last years giving rise to more and more wireless-based systems. IoT technology is widely being utilized by the cultural heritage sector to establish the lost sparks from their static environment for developing entertaining and interacting environment. However, current wireless systems have taken advantage of emerging sensory technologies in smartphones which led to a new way of exploration and dissemination of cultural activities and sites. This paper proposes some prototyping scenarios to develop co-design sessions. These sessions will enhance the tourist playful experience and dissemination of cultural heritage activities. Furthermore, through the proposed scenarios, this study describes the development steps and stages of an IoT application that disseminates cultural heritage. The paper also explores the hurdles and difficulties a research team faced while developing the IoT-based application for cultural heritage dissemination.The study proposed method how to develop internet of things prototyping for cultural heritage dissemination

Keywords: *Internet of Things, Prototyping, Design Process, Cultural Heritage dissemination.*

1. Introduction

The connection between new technologies and the cultural heritage domain has always been dialectical, multifaceted and repeatedly inspired by the people need to follow technological trends, ultimately offering devices and novel technologies to the end-users that might become a burden during people cultural heritage experience. Yet, using novel technological applications it is possible to reduce the distance between visitors and cultural places, determined by the merely aesthetic and vital passive fruition of cultural items (Chianese, Piccialli & Valente, 2015).

Cultural Heritage represents a source of identity and cohesion of groups disrupted by bewildering changes and financial instability (UNESCO, n.d.). Cultural Heritage is divided into two classes: natural heritage and strictly cultural heritage. Generally, buildings, monuments, landscapes, books, artefacts and works of art are considered tangible culture and tradition; language knowledge and folklore are considered intangible culture.

Cultural heritage sites are contributing to the countries' economic growth, but it is time to have potential policies in place for cultural heritage sites preservation. UNESCO's findings indicate that there are more visitors in cultural heritage sites globally, but some sites are getting neglected in terms of preservation (Robinson & Picard, 2011). Supervision of cultural heritage sites will be the first step in an organized approach, not only to preserve the present cultural heritage sites but also to provide upcoming generations with easy access to traditions, norms and values of their forefathers.

Internet of Things (IoT) is a worldwide structure for the communication and information community, enabling sophisticated services by interconnecting virtual and physical devices based on existing and

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growing interoperable communication and information technologies (ITU, 2012). It is envisioned that an atmosphere with billions of physical, virtual devices and information objects are connected through unique network protocols. The concept of IoT includes a world that is equipped with smart devices, cars, smartphones, smart homes, smart cities and smart cultural heritage sites (Stankovic, 2014). Through IoT, physical objects and devices are easily integrated into an Internet-like system so that physical devices and objects can interact with each other, cyber agents to accomplish mission-crucial goals (Lin et al., 2017). IoT is a unique networking infrastructure for CPS (Cyber-physical systems), designed systems that are built from and depend upon the seamless integration of physical devices or objects and computational algorithms (Lee, Bagheri & Kao, 2015).

Another technology that is playing a vital role in Cultural Heritage dissemination is Augmented Reality (AR). AR is considered one of the most advanced technologies that combine the virtual world and the real world. AR is real-time data from the components which are augmented through computer-generated virtual information, such as sounds, graphics, GPS, and video data (Vichivanives & Poonsilp, 2018).

Virtual Cultural Heritage in AR can be described as interactive computer-based technology that can be used to accomplish visual reconstruction, such as culture, buildings and artefacts (Bruno et al., 2010). AR is used to preserve delicate historical sites, and buildings from vandalism and natural disasters (Núñez Andrés, Buill Pozuelo, Regot Marimón, & de Mesa Gisbert, 2012). For a virtual heritage environment, seven design rules must be considered, for example, high level of automation capture for all cultural detail, low cost, high accuracy, geometric measures, size efficiency portability, flexibility, and photorealism (El-Hakim, Beraldin, Picard, & Godin, 2004). Cultural heritage sites layers are proposed to envisage historic content and material such as photographs and paintings of ancient buildings, historic landscapes seamlessly superimposed on the real environment through images, painting and video using X3D (Zoellner, Keil, Drevensek, & Wuest, 2009).

This paper defines the procedures to develop a first stage IoT and AR-based Android application prototype, including different scenarios. The purpose of prototyping these scenarios was to support co-design sessions, which will allow Amiais' inhabitants, stakeholders and visitors to actively participate in the construction and definition of the app. The prototyping also aims to introduce the potential of technology, namely IoT, demonstrating how everyday objects can be digitally enhanced.

Considering the lack of digital skills of Amiais' inhabitants, the use of this prototype was intended to facilitate the effective participation of the elderly in the design process, enhancing the ability to imagine new scenarios and narratives and other ways of using technology. The app will disseminate cultural heritage sites, cultural activities, and cultural folks' stories. This prototype is being developed in LOCUS – playfuL cOnneCted rUral territorieS, a scientific research project which aims to combine playful activities, IoT, AR and intergenerational learning processes of Cultural Heritage.

During this stage of LOCUS implementation, an AR mobile application was developed. This application contains four scenarios that include image recognition, object recognition, GPS location and AR. The app provides IoT connection with which the user can experience different options to explore cultural heritage sites and monuments (using resources as Bluetooth, smart sensor Arduino Board, led lights, micro speakers, and gyroscope).

2. Literature review

Cultural Heritage is one of the legacies of ancient people. It includes their memories and experiences (as well as places and monuments), but also the information that is passed to the next generations. The United Nations Educational, Scientific and Cultural Organization (UNESCO) offers a Cultural Heritage definition, which contains three dimensions: sites, groups and monuments (Shepherd, 2006). These are of remarkable worldwide value from an aesthetic, ethnological and historical point of view (UNESCO, n.d.).

Moreover, the term culture has been defined as a multifaceted concept, meaning the acquisition of specific elements by the members of a community which includes arts, knowledge, beliefs, laws, traditions, moral and other abilities and lifestyles (Manganaro, 2002). The academic researchers have offered some kind of tools to analyze culture properties and operationalize it (Hofstede, 2001).

Various studies have proposed some components of a culture such as polychronic or monochronic, low and context cultures (Carnahan, Agarwal, & Campbell, 2010; Hall, 1959; Nishimura, Nevgi, & Tella, 2008). Another example is Kluckhon's five types of attitudes to problems response to compatriots, time, a form of activity, and nature (Ervin, Kluckhohn & Strodtbeck, 1963; Hills, 2002). Hofstede's 6D prototype of power collectivism versus individualism distance, indulgence versus restrain, uncertainty avoidance, feminism versus masculinity and short term versus long term (Hofstede, 2010). Moreover, Tropmenaars offers seven dimensions of culture such as individual versus collectivist, universalist versus particularistic, specific versus diffuse, neutral versus affective and achievement-oriented versus ascriptive (Charles Hampden-Turner, 2011).

Most of these studies along with ongoing World values survey (www.worldvalues.org) are based on the recognition of mutual cultural values at a nationwide level (Victor, 1992). Hofstede's cultural dimensional analysis is used widely in the User Interface (UI) and User Experience (UX) design fields. Two main reasons have been reported for this: the first one is that cultural dimensions can be associated with tangible UI (Reinecke, Katharina , Bernstein & Abstract, 2013) and the second is the possibility shown in an empirical study of the implementation of these tools in a very large scale (Marcus & Baumgartner, 2002).

Among in the HCI(Human-computer interaction) communities, and institutional bodies of research analyzes the design, evaluation and development of technology-powered interactive exhibitions in a variety of cultural heritage settings. The consumers of such technologies have been considered to be the tourists and research is inclined to put its emphasis on tourists' experience of interactive relics in a cultural heritage exhibition and in the way this experience can be enhanced and supported (Taxén, 2014).

Though tourists are the ones who eventually interact with these relics and artefacts in cultural heritage sites, it is not giving the same attention to the job of cultural heritage specialists informing and often preserving such installations. Cultural heritage specialists are often taken as consultants in the majority of technology design endeavour in the heritage sites context such as museums (Bortolaso, Bach, & Dubois, 2011; Dindler, Iversen, Smith & Veerasawmy, 2010; Maye, Bouchard, Avram & Ciolfi, 2017; Salgado, 2013).

Cultural heritage sites, especially museums, have begun to study what a design methodology could bring to the plotting of an overall new cultural heritage (museums) sites experience (MacLeod, Dodd & Duncan, 2015).

For prototyping, design thinking can be defined as the process in which developer and designers approach the solution of the issue. But the very initial step is not to resolve problems but to improve understanding about the problems: it is ‘problem setting’ before problem-solving (Brown, 2019; Dorst, 2011). Design thinking is a practice-based field so producing and trying out is ingrained in it. It is a non-linear iterative development procedure that regularly works via inspiration and knowledge, reflection, evaluation, ideation and implementation. In the designing process, human experience is considered a synonymous of human-centred design (Derby Museums, 2018; Mitroff Silvers, Dana, Wilson & Rogers, 2018).

Design thinking is a process that led the way to explore problems which are constantly raising questions and the choices made and keep several options open until empirical evidence is collected to help in the decision-making process. For its suppleness, reliability and openness design thinking processes are very engaging as they empower each person to perform an equal role. Whereas design thinking describes a process of how to develop a product, the co-codesign concept captures the actors, who can be users and stakeholders who participate in the design decision-making process. The essence of the generative association is at the foundation of co-design. Participative models in museums have been valued for their capacity to generate novel concepts or to significantly evaluate present ones (Taxén, 2004) through the participation of intended people (Bossen, Dindler & Iversen, 2012).

The examples of cultural heritage experts as co-designers are only a few and illustrate how a strong association with designers can be able to create very novel solutions (Ciolfi et al., 2016) or cultural heritage professionals can autonomously create an AR experience for tourists through effective tools and applications (Maye et al., 2017). By applying simple and comfortable techniques, for example, acting, post comments and sketching, co-design methods allow participants with very different qualifications to take part and feel they own the product design.

In co-creation methodology, three groups, such as developers, designers, and community members share their experiences, ideas and knowledge for the development of the prototype. Then, researchers, developers and designers develop an initial design of the prototype and present it to participants to probe for initial understanding. After that, the presented prototype helps to understand the problem in-depth. Lastly, designers present an initial design of the prototype to the participants, how the prototype design was based on participants ideas, feedback and knowledge. Participants’ feedback of semi-completed prototype helps the ultimate design of prototypes and provide information about users' understanding. In the prototyping process, the designers play a facilitator role (Elsbach & Stigliani, 2018; Isa, Liem & Steinert, 2015).

3. Methodology

This literature review provided a deeper understanding of the LOCUS project prototype to develop a different and novel product that allows for explorations, design, detailing stages and conception through the participation of stakeholders, visitors and inhabitants to capture the cost-rich end-user experiences.

First, semi-structured and informal interviews were conducted in Amiais village, with stakeholders and inhabitants. The goal of these interviews and conversations was to explore the local cultural heritage, including monuments, but most importantly, past playful activities and memories.

As LOCUS aims to work with real-objects, the study was angled towards exploring the real-life phenomenon comparatively to a person (ZDEL et al., 2018). Prototyping goals of the LOCUS project are encouraged to engage the Amiais village community in the early exploration development and design activities through co-design methodologies. The primary design of the prototype was developed through interviews and analysis of local literature about the location.

The study followed three phases. The first was to visit Amiais and interact with locals and stakeholders, with the motivation of getting a perception of people, their knowledge about the local cultural heritage and their digital literacy and attitudes as to IoT and AR. Secondly, to present an initial design of the IoT-based application. Lastly, to test the application with Amiais' stakeholders, inhabitants and tourists.

Four possibilities were developed in the LOCUS prototype: AR, object recognition, image recognition and GPS location. For each one, some specific scenarios were elaborated, with the main goal of testing them with Amiais' inhabitants, stakeholders and visitors. They are described below.

3.1. Instruments, techniques, and participants

The study was designed to be implemented in Portuguese context, namely the desertified rural areas, which, precisely because of the desertification phenomen, are at risk of losing all its cultural heritage.

The selected population was the Amiais' village. From the previous studies LOCUS research team implemented, it was possible to conclude that Amiais' inhabitants digital literacy rate is not very high, most population cannot read and/or write properly, nor do they possess digital devices (smartphones, tablets, etc.). Therefore, it is difficult to provide written material and collect feedback in written form.

In most cases, the collected data takes the form of oral interviews and informal conversations. Firstly, we took the pre-design interview, to know the perception of inhabitants about technology and their digital expertise. Based on the pre-design interview, the prototype was developed.

The goal is to test the prototype with Amiais' inhabitants, but because of the pandemic situation, this stage of the project is waiting for the encounters in Amiais to restart.

3.1.1. Location

Amiais village has been selected due to its location, essential cultural festivals, and traditional agricultural activities. Amiais is a Portuguese village situated in Couto de Esteves Parish, in Sever do Vouga municipality, Portugal. The village is culturally enriched, and it is surrounded by green vegetation, magnificent landscapes, and mountains scenery. There are many religious festivals in Couto de Esteves parish: Santissimo Sacramento; São Francisco de Assis e Nossa Senhora do Amparo. Furthermore, there is a folk Portuguese traditional place called *Eira comunitária.* In this context, *Eira comunitária* was a place where, traditionally, the people from the village gather for threshing corn, by adopting an ancient method. For threshing, there is a wooden made stick that is consisting of two sticks, one is long and second is short that is connected at one end by a short chain or rope. Likewise, the men and woman hold the long part of the stick and hit the small part that connected with a chain on the corn for corn threshing.

3.2. Scenarios prototyping

Engineers, researchers and scientists often refer to envisaged socio-technical characteristics when developing novel technologies, at least if these developments diverge from strictly incremental innovations. These future ideas are often much less common than visions usually are. Instead, researchers and scientists depict in some detail how the envisaged future will possibly look. (Schulz-Schaeffer & Meister, 2017). In this study, researchers have envisaged two kinds of scenarios: one based on AR and another on IoT. The prototype includes object recognition, image recognition, photo upload and GPS location. These functions are described below, as well as the scenarios that were recreated.

3.2.1. Object recognition

IoT is a concept concerned with bringing pervasive internet connectivity to real-world objects or things (Atzori, Iera & Morabito, 2010). Such IoT scenarios open opportunities for a variety of different computing devices to interact and communicate with each other. Envisioned smart products entail but are not limited to smart healthcare, smart cities, environmental monitoring, smart buildings as well as smart businesses (Miorandi, Sicari, De Pellegrini, & Chlamtac, 2012). Likewise, the LOCUS prototype was developed to include a scenario with which Amiais' inhabitants will relate to.

The following steps of this object recognition scenario consist of providing the possibility of different objects to connect. For example, when three objects are closer (object A, B, and C), and the user manipulates object A in a certain way, it turns on a light in object B; when the light of object B is turned off by the user, object C vibrates or makes a sound. Therefore, object recognition is the first step for IoT integration.

IoT hardware contains a wide range of tools such as devices sensors, bridges, and routing etc. This IoT hardware manages key functions and tasks like security, system activation, communication, specification, actions and deletions (Trilles, González-Pérez & Huerta, 2018). In this regard, this study uses a wide range of hardware and software to develop effective IoT scenarios. The following hardware has been used in this study.

Table 1. Hardware and software for initial IoT developments

Hardware	Software
Bluetooth	Arduino IDE APP for programming C++ Java
Arduino UNO	
Gyroscope	
HC-12 Communication module	
Led lights	
Small loudspeaker	
Batteries	
Pushbuttons/switches	

3.2.2. Image recognition

For this activity, a paper box cube was used, where each side of the box (except for top and bottom) displays one image of Amiais' village. These images represent a different aspect of Amiais.

Side A:

It contains an Amiais' typical image. When the user points the smartphone to this side of the box a text is displayed informing the user of how the activity of threshing corn is performed.

Figure 1. Corn picture (taken at Amiais)

Side B:

Side "B" of the box displays an image of a water mill that is situated in Amiais. The watermill image is embedded with the sound of grinding.

Figure 2. Traditional windmill (Source: LANCE)

Side C:

Side C of the box displays an image of a traditional religious stone, named “Alminhas”, and is embedded with a GIF.

Figure 3. Traditional religious stone, Alminhas

Side D:

Side “D” of the box displays an image of the place where the corn was kept (Espigueiro) awaiting the best time for threshing corn. The image is embedded with a small video documentary of Amiais’ village. This video documentary represents different religious and cultural festivals that occur in Amiais.

Figure 4. Espigueiro

AR is the overlapping of computer-generated pictures on the real world using a see-through display. The usage of mobile AR is becoming part of daily life in many developed countries. For AR experiences people are using different tools such as AR glasses, necklaces, wristwatches, and clothing embedded technology (Interrante, Höllerer, & Lécuyer, 2020).

With image recognition, the goal was to provide the first step for AR experiments, such as overlapping past images with current ones, and videos.

To develop LOCUS scenarios, the following hardware and software were used, to approach an AR development.

Table 2. 1Hardware and software for Augmented Reality

Hardware	Software
Android cellphone	Unity 3D
DSLR	Android studio
Gyroscope	Vuforia plugin
	C++
	JAVA
	Wikitude plugin
	AR+GPS unity plugin

3.2.3. Photo upload

This is a very unique feature of LOCUS, in which the user will have the option to use the device camera for picture capturing and tagging with location and sharing on social media platforms.

3.2.4. GPS location

LOCUS mobile app also offers the possibility for the user to tag his/her location. The app uses a AR+GPS plugin from unity that has reliable accuracy. GPS features will have very minimum chances to jeopardized the tests because AR+GPS are designed to display in remote areas, they have very reliable and effective feaures. This plugin helps to tag text, video, and image with locations through georeferencing. Video and text information is embedded with a different location of Amiais, for example when users visit a certain part of Amiais' village and turn on the LOCUS application, immediately user will have information of that location in video, audio and text. This information is embedded in different locations of Amiais through GPS.

3.3. Scenarios' prototyping operationalization

After defining the AR and IoT scenarios, this study developed a LOCUS primary prototype. In this context, this section describes how the prototype works and what the characteristics of this prototype are. The design of this prototype contained two main features: Augmented Reality and the Internet of Things.

3.3.1. Prototype AR characteristics

To try the LOCUS scenarios prototype, the users will need to use an android device. LOCUS app should then be installed. When opening the app, the home screen will appear (figure 5) and four possibilities are displayed (the ones previously described): image recognition, object recognition, AR experience (geolocation) and open camera. When the users select each option, the tasks described before are initiated.

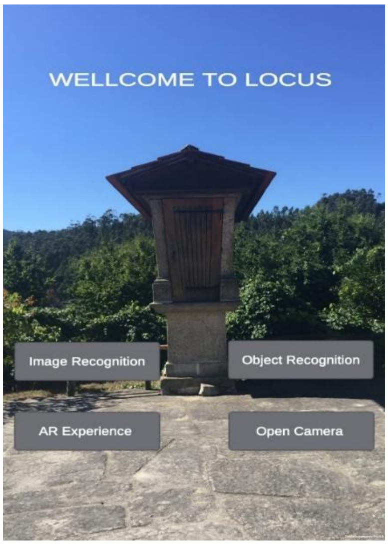

Figure 5. LOCUS Android application

3.3.2. Prototype IoT characteristics

LOCUS scenarios prototype provides a very comprehensive scenario for its users. Users will have three objects and each object will be tagged with letters A, B and C. Objects will be tagged with MPU-6050 accelerometer, gyroscope, Bluetooth, HC-12 with Arduino UNO. When the user holds object A and moves it in a certain angle, object B activates via HC-12 communication module and turns the LED lights on. After that, the user will push the button and turn the LED lights off. Object C will immediately activate through the HC-12 communication module that activates traditional Portuguese music. These three objects communicate with each other and pass all information to the android application via Bluetooth technology. Figure 6 graphically represents this option.

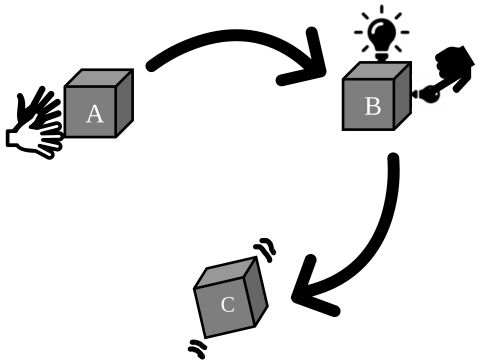

Figure 6. IoT operationalization

4. Conclusions and difficulties faced in prototype development

Until now LOCUS made enormous developments. It approaches Amiais' inhabitants, stakeholders and visitors. It made an exhaustive list (with a detailed description) of the main cultural facts, playful activities, historical memories, ancient pictures and stories. This was the starting point of LOCUS and was developed to allow the implementation of the LOCUS mobile app with its AR and IoT features. At this moment the app is already being developed with the options described before, but these first conclusions are meant to mention the challenges and hurdles the LOCUS team encountered and how some of them were overcome.

4.1. Challenges in selecting development platforms (software and hardware)

During these first development phases, LOCUS team worked on numerous platforms and software options which were already used in similar projects, regarding cultural heritage sites, ranging from solo interactive instances to finalized interactive applications (Marshall et al., 2016; Petrelli et al., 2018).

LOCUS research team found subsequently that cultural heritage phenomena offer interesting challenges for the development of IoT and AR applications. First and foremost, selecting software and development platforms. Software and development platforms are very expensive. Where possible, the LOCUS team attempted to mitigate prices, whether by finding free development platforms and software or at least select the most affordable software. In this regard, free platforms for AR development were selected, such as Unity 3D, a platform which helps develop AR content for websites, android and IoS devices with the help of a third-party plugin.

LOCUS team selected the Vuforia development plugin that is free of cost but includes a Vuforia watermark in the app. Vuforia is helpful for image recognition. The Vuforia plugin does not work effectively for object recognition because for object scanning the app only works perfectly with a few mobile devices such as Samsung S10, iPhone 10 or more. The LOCUS smartphone app was able to scan the object but scanning a file into Unity 3D was used, and it kept giving an error.

As an alternative to Vuforia, the Wikitude plugin was used, namely for object recognition. It is free but also includes a watermark. Wikitude and Vuforia are not compatible with GPS Augmented Reality.

Therefore, another solution was used: the GPS+AR plugin from Unity 3D assets. It is not a free plugin but it is affordable.

Furthermore, the Amiais village does not have wire internet services and cellular services signal is very weak because it is located in a very remote area of Portugal where few houses and cultural heritage sites exist. To overcome this constraint, an app that does not require internet services for AR was developed. LOCUS App is already equipped with GPS technology and AR+GPS Unity assets that is accurate, specially in remote areas.

4.2. Social challenges

Some social challenges, along with technical ones (mentioned above) were found. The Amiais inhabitants are of great importance for the project, namely because they possess all the knowledge about local cultural heritage, the monuments, playful activities and stories. But LOCUS has an important digital dimension, considering, as seen, the use of advanced technology (AR and IoT). Making these two dimensions meet – the keepers of cultural heritage knowledge and the use of advanced technology – is a challenge in itself. Mostly because those inhabitants are more than 50 years old and do not have the skills or even the tools to use smartphones. LOCUS team has thought of several ways to overcome this challenge such as, participants would not feel constrained to participate and they are taken on board as members of the research team. LOCUS strives on the joint construction of knowledge.

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