

Artigo

Design Guidelines for Development of Augmented Reality Application with Mobile and Wearable Technologies for Contextual Learning

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Abstract

Contextual learning is broadly linked to constructivist theory of learning. Learning take place when people are able to construct meaning based on their own experiences. With the advancedments of technology enhanced learning, recently contextual and informal learning has attracted huge attentions for development and deplyment. Recently through the use of Augmented Reality (AR), which is relatively new technology, interaction provided between the real world and a computer- generated digital content. Augmented Reality can offer interesting, engaging and immersive content and interactions, which may enhance learning experiences. However, designing for augmented reality application has thrown a number of challenges for designer and developer to address, which is not only related to the usability of interface and interactions, but also implications for learning in general and for contextual learning in particular. Research to date boradly addresses some of these challengese, however there are very few design guidelines for AR technologies that can enhance efficiancy, effectiveness and users satisfactions. This project develops novel sets of interaction design guidelines through the user centred design investigation unravelling a potential of augment reality for contextual learning. We presents a number of studies carried out to gather users requirements and experiences for successful development and deployment of this rapidly advancing technologies. The ARCity mobile application is presented as a proof of concept facilitating a contextual and cultural learning using mobile augmented reality technologies.

Keywords

Location-based Mobile Learning, Ubiquitous Learning, Contextual Learning, CloudBased Computing, Smart Cities, Augmented reality

Resumo

A aprendizagem contextual está amplamente ligada à teoria construtivista da aprendizagem. A aprendizagem ocorre quando as pessoas são capazes de construir significado com base em suas próprias experiências. Com os avanços da tecnologia, a aprendizagem aprimorada, recentemente a aprendizagem contextual e informal atraiu grandes atenções para o desenvolvimento e o trabalho. Recentemente, através do uso da Realidade Aumentada (AR), que é relativamente nova tecnologia, a interação proporcionada entre o mundo real e um conteúdo digital gerado por computador. A Realidade Aumentada pode oferecer conteúdo e interações interessantes, envolventes e envolventes, que podem melhorar as experiências de aprendizado. No entanto, projetar para aplicativos de realidade aumentada lançou vários desafios para o designer e o desenvolvedor abordarem, o que não está relacionado apenas à usabilidade da interface e das interações, mas também às implicações para o aprendizado em geral e para o aprendizado contextual em particular. Pesquisas até o momento abordam alguns desses desafios, no entanto, existem muito poucas diretrizes de projeto para tecnologias de RA que podem melhorar a eficiência, a eficácia e a satisfação dos usuários. Este projeto desenvolve novos conjuntos de diretrizes de design de interação através da investigação de design centrada no usuário, desvendando um potencial de aumento da realidade para o aprendizado contextual. Apresentamos uma série de estudos realizados para reunir os requisitos e as experiências dos usuários para o desenvolvimento e implantação bem-sucedidos dessas tecnologias em rápida evolução. O aplicativo móvel ARCity é apresentado como uma prova de conceito que facilita um aprendizado contextual e cultural usando tecnologias móveis de realidade aumentada.

Palavras-chave

Aprendizagem Móvel baseada em localização, Aprendizagem Ubíqua, Aprendizagem Contextual, Computação Baseada em Nuvem, Cidades Inteligentes, Realidade Aumentada.

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Introdução

The notion of contextual, ubiquitous, and seamless learning has been recently transcended into the research in mobile learning. In 21 century, the advancement of ubiquitous, mobile, tag-based and wearable technologies and the power of Internet, and cloud-based computing, enable us to be seamlessly connected, and therefore, as the results to be continuously empowered to explore different context and situations. Learning opportunities might be drawn from the situations around us or from the context, and location that we may discover. In contextual learning, awareness of the context and location can be detected by mobile, tag-based and wearable technologies.

There are a number of projects (ABOWD et al., 1997; ROGERS et al., 2004; BROWN et al., 2010; BROWN, 2010; SCHMIDT-BELZ et al., 2003), aimed to explore a potential of ubiquitous, and contextual learning, however we still know very little of how learning design can be tailored for individual and group of users using the mobile augmented reality (AR) technologies. Augmented reality has been used in recent years as a tool for enhancing collaboration between the real world and virtual environments. There are many examples of application domains where these collaborative Augmented Reality Systems are being applied such as education, urban planning, and outdoor Entertainment (ZIPE, 2002; CHEVERST; DAVIES; MITCHELL; FRIDAY, 2000; SIMCOCK; HILLENBRAND; THOMAS, 2003; POSLAD et al., 2001; NAISMITH et al., 2005; FALLAHKAIR, 2011). In order to support the creation of collaborative augmented reality, it is necessary to have access to seamless interfaces, which allow interacting with virtual and real objects at the same time. The current generation of mobile phones offers an ideal platform for the application of collaborative augmented reality, due to the co-located characteristics that it provides, such as GPS and Wi-Fi support, multi-modal interaction paradigms, and the massive penetration of these devices in the worldwide population (CLOUGH, 2010; NAISMITH; SMITH, 2004).

Taking into account that informal learning and tourism are part of outdoor educational application domain, this field offers a desirable environment to apply the concept of the use of augmented reality using mobile phones as collaborative interfaces. Although augmented reality and its practical applications have been a research topic during several years, a constant obstacle was a lack of guideline for development of usable and useful augmented reality interface, and interaction.

This research aims to contribute towards unravelling a potential of mobile augmented reality applications to support contextual and informal learning in the context of cultural tourism industry. Our broad objectives were to identify the main benefits of the use of mobile application based on location based augmented reality interface and to implementation and evaluate the use of an android native mobile application as a proof of concept. This project aims to develop and devise a list of novel design guidelines for developers of augmented reality systems with mobile and ubiquitous technologies. We start our discussion with the review of related literature (section II), followed by details on methodological approach (section III), then we discuss the requirement engineering, de-

sign and development of ARCity application as a proof of concept (sections III, IV and V), followed by evaluation study that have been carried out to evaluate the usability usefulness and implications of the augment reality application to support contextual and informal learning (section VI). Finally, we provide our concluding remarks and novel set of interaction design guidelines (section VII).

Literature review: mobile and augmented reality technologies for contextual and informal learning

The rapid advancement of mobile technology over the last decade, and the merging it with the learning have given promises to free people from space and time restriction, providing opportunities for people to learn regardless time and place (FALLAHKAIR, 2011; LOOI et al., 2010; WONG, 2012; CHAN et al., 2006; WONG; LOOI, 2011; BELL, 2000; SO, 2008; CHEN; SEOW; SO; TOH; LOOI, 2010; WONG; LOOI, 2012; UOSAKI; OGATA; LI; HOU; MOURI, 2013; MILRAD; WONG; SHARPLES; HWANG; OGATA, 2013).

Cultural sites in cities can be transformed in an intelligent environment providing opportunities for informal and contextual learning. The first evidence of AR project came from Sutherland work in 1960 with the use of a head- mounted display (HMD) to display three dimension graphics. In 1997, Ronald T. Azuma published a survey consolidating the current development in Augmented Reality area and describing the potential problems related with this field (AZUMA; BAILLOT; BEHRINGER; FEINER; JULIER; MACINTYRE, 2001). Since then, there has been increasing development in this area due to advancements of hardware and software in computing systems. Obaidat, Denko and Woungang (2011) define an intelligent or smart environment as an environment that is capable to obtain and apply knowledge about the environment and allows to adapt to it is inhabitants requirements with the aim of improving their experience. Furthermore they indicate the character of intelligent environment demands new human-computer interaction patterns. These patterns require interfaces with the following features: (a) adapting to the environment and to the user's requirements; (b) learning from experience; and (c) the capability to react to gestures. Consequently, an option to obtain an intelligent environment is the use of pervasive computing. The realization of ubiquitous and pervasive computing enable to make use of the environment around the user for advancing interactions, regardless time and space.

Leichtenstern and Andre (2008) suggest smartphones as context- awareness interfaces. In fact, features of hardware (camera, GPS) and network interfaces (UMTS, WIFI) enable new presentation and interaction techniques that give to smartphone capabilities to become as a pervasive interface.

Characteristics of augmented reality can be considered as a variation of Virtual Reality. Whilst a virtual reality may replace use of real environment by a virtual one, augmented reality presents the user the real world with virtual objects complemented to it. Azuma, Baillot, Behringer, Feiner and Macintyre (2001) have presented some several characteristics of Augmented

Reality as it: combines real and virtual objects in the real world runs interactively, and in real time registers (aligns) real and virtual world with each other. The definition of Augmented Reality and its characteristics prevents limiting Augmented Reality to specific technologies such as HMD while retaining the main functionality of AR.

Nevertheless, Augmented and Virtual Reality is commonly narrowed only to sight sense; however, it may also be applied to the other senses like sound (AZUMA; BAILLOT; BEHRINGER; FEINER; JULIER; MACINTYRE, 2001). The presented features of augmented reality give the opportunity to enhance the user's perception and interaction of the real world, through the virtual objects superposed on it. Moreover, the information contained in the virtual components strengthens the interaction with the real environment, due to help to the user to perform common tasks. Brooks (1996) named this phenomenon as Intelligence Amplification (IA): using the computer as a tool to convert a task easier for a human to perform.

There are a number of approaches for utilization of augmentation in reality. One common approach is to use optical or video technologies (AZUMA; BAILLOT; BEHRINGER; FEINER; JULIER; MACINTYRE, 2001). With the use of optical devices, the user can see directly the real world through it. On the other hand, video devices provides the user's view of the real environment. Taking into account for developing mobile application, it is feasible to use the advancement of smart devices to detect, sense, interpret and respond to aspects of a user's local environment and the computing devices themselves. The particular characteristics of mobile devices make it easier to exert these features in the implementation of mobile applications. Some examples include/ the tourist guide Application for the city of Vienna is an augmented reality application that provides to user navigation aid in order to allow tourists to reach target location. Also, the application has an information browser that displays location referenced information (CHAN et al., 2006). A mobile guide system that allows the integration of the art appreciation with Augmented Reality also developed by Chan et al. (2006), which enables and enhance learners' experiences for visiting an art museum.

The following sections present the methodological approach for this project as well as detailed of technical solutions on design and development of augmented reality application (ARCity), followed by some detailed discussions on our design, development and evaluation.

Methodology

In this project we use the socio-cognitive research methodology (SHARPLES et al., 2002), which aims to involve potential users by incorporating their knowledge into the design process. Mainly through field studies and requirements engineering processes, we attempted to understand more about potential users.

For gathering requirements as Leichtenstern and Andre (2008) suggested we have used "usage model schema" as a choice for requirements definition allowing us to describe the usage of the mobile interface, including all aspects of context, and computing environment. Through the user-

-centred process of socio-cognitive engineering, we have developed a proof of concept, ARCity app, which have used the latest technological development in cloud-based infrastructure and wikitude AR browser for Android platform using Restful architecture.

For evaluation, we have mainly used qualitative methods to evaluate usability and usefulness of ARCity, including observation, interview. In addition to qualitative method, we have conducted a small scale usability questionnaire using SUS method for evaluating the interface. The evaluation study has been conducted in Cultural Places in Brno Czech Republic. The ARCity app has been installed and evaluated using the Android platform. A full account of evaluation study has been discussed in the evaluation section in this paper.

Requirements for augmented reality application

We have conducted an empirical study to gather a list of general requirements. A qualitative method used to collect data from randomize sample of international students that expressed their interests in using mobile technologies and applications. Volunteered were asked to take part on the study for a period of two weeks, and to report on any learning experiences and opportunities as they encounter whilst using mobile technologies in an out-door setting. Participants could use any form of notebook or devices to record of their learning experiences, either in textual or audio format. We have collected 1134 entries that were recorded in textual format (1126) using notebook and in audio format (8) using audio recordings device. Data were collected, were subsequently transcribed and analyzed using content-based analyses and thematically presented using (LEICHTENS-TERN; ANDRE, 2008) pervasive computing usage model in order to outline themes considering environmental, social, and technical context, assisting us to devise a list of general requirements. The general requirements elicited form the following broad categories:

Enhancing public understanding of the environment

There were (1302) entries mentioning that participants were appreciate learning more about the environment, “ I like to learn about nature and different kind of species while I am in different environment”, another example, “Learning in different context and environment help to remember things”, “we always love to go to holidays to collect experiences and learning about target culture and environment”. Participants were enthusiastic about using mobile technologies to show enhance their experiences of different location by providing relevant information about the context and environment, i.e. brief description of the place, photos, and so on. Also, the functionality to allow users to find their way around and navigate using features such as map was mentioned.

Encourage visitors to increase interaction with the place visited and with each other's

There were (997) entries mentoring that participants were enthusiastic about the social aspect of learning. Research indicates that tourist experiences could be improved through communication activities. One of these activities is giving opportunities to visitors to first- hand active involvement and use of their senses with the objective of promotes self-discovered insights. Parti-

participants mentioned that they prefer to be engaged to interact with others while visiting a new place, for example to share comments and feedback about a particular site or point of interest and also to be enabled to provide their own rating or view other people feedback.

Enable visitors to collect and store learning experiences

There were (546) entries mentoring those participants were mentioning about the advantage of being able to collect and store digital content in the form of images, audio, video or textual whilst visiting the sites and being able to share their experiences with others. Some people mentioned about using features similar to Facebook, however, others were more interested to collect their own experiences individually and anomalously on the mobile device, but they appreciated more features to help them to search more effectively. This study has suggest a broad range of requirements that could be used to conceptualize a number of different systems to support learning in an out- door setting. For this project we have decided to focus on the requirements that could assist contextual learning within a target environment whilst visiting touristic places and on-the-move. The summary of the requirements elicited are presented in Table 1 which has been used for the design and development of ARCity app.

General Requirement (GR)	Description	Categories
GR1	The application shows touristic places around user location mixing real environment (camera view) with Augmented Reality objects shown in a form of proportional circles depending Distance.	Environmental /Technical
GR2	The application must give the option of select a place from the screen by touching the circle associated with that place. when the user clicks on the circle, the colour of this circle must change	Environmental / Technical
GR3	When the user selects a place by clicking on Augmented Reality Object. The application must show the following information: Place Details, Distance, Type of Place, Description, and Rating.	Environmental / Technical
GR4	The application must show a radar object with the touristic places nearby the user location. These places will be displayed in the radar according their relative position	Environmental /Technical
GR5	The user must have the option to rate a selected place by submitting rating, comment and detail of comment.	Environmental /Social/Technical
GR6	The application must display a button in the information details section that allows the user to show a map with directions from the user location to selected place.	Environmental /Technical

Table 1 – General Requirements (GR)

Design and development of augmented reality

This section provides all details of technical discussion for design and development of ARCity application, which is developed for Android platform. The application enables users to view touristic places nearby on the augmented reality mobile display, for example in the following scenario, the picture of Guildhall, Portsmouth, UK is provided with some description about the importance and history of this place. Users can view, select and get directions to navigate to see other important places around them. In addition, the system enables users to take pictures and to provide rating and comments of a particular palace of interest. Figure 1 demonstrates ARCity application.



Figure 1 – ARCity Application

System Architecture – Service Oriented Multi-tier, Cloud-Based Architecture

A critical point during the development of this project was to choose an architecture pattern that could be scalable, allowing the deployment of business process changes, reuse of behaviours and interoperability between different platforms. It was imperative that the best option would be a hybrid architecture between Service Oriented Architecture and Cloud Computing. The Architecture Model applied to this project contain two main blocks: Service Consumer and Service Provider. The Service Consumer includes the Android native application, which contains Augmented Reality framework and calls the front-end component of the application. The front end component, based on web technologies (HTML,CSS and JavaScript), is bound to the service provider through the use of communication with JavaScript Open Notation (Json) messages between Web Services. On the other side, the service provider, which contains the back-end component of the application, responsible for including the business rules and processes of the application. The components of the Service Provider are: a MySQL DataBase Server, a Java EE Application, JBOSS Application Server and Google API. These components are encapsulated into a Red Hat's Platform-as-a-Service called OpenShift® that allows to host and scale applications in a cloud environment (see Figure 2). For addressing structure and dependencies, the source code is structured using the patterns of Java EE Application. However, as we need to manage JSON data flow between back-end and front-end tier.

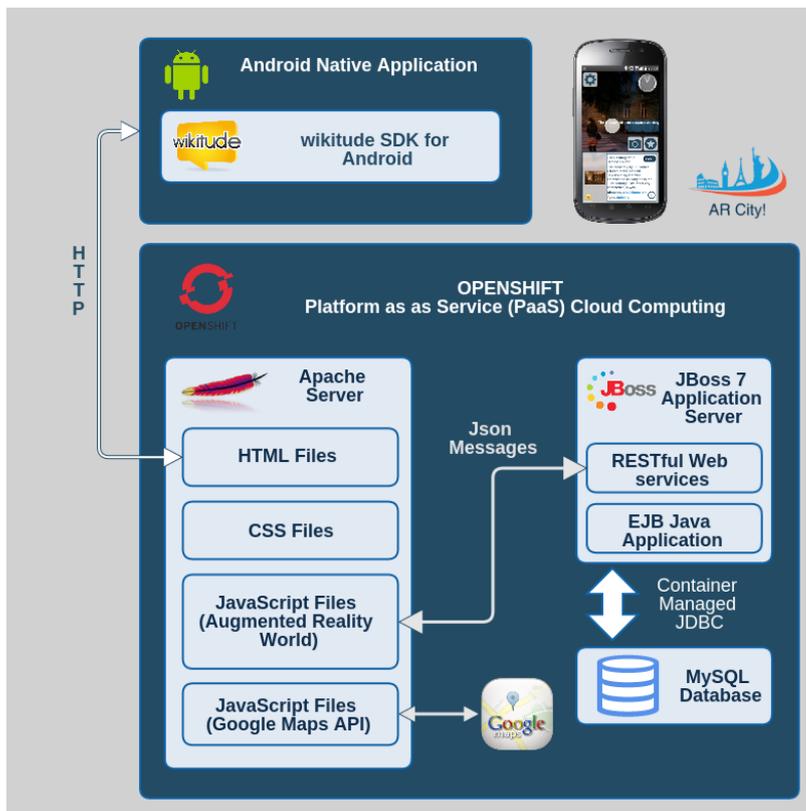


Figure 2 – System Architecture

Evaluation

An evaluation of the prototype was carried out using a combination of observations, interview, and questionnaire. Data were gathered in different dimensions to test the usability of the software itself, the usefulness and benefit of the features provided. The main aim was to explore how useful an application, such as ARCity would be and how further improvements can be made in the future. In order to evaluate AR City cultural tourism application, the android native application was tested in the city centre of Brno Czech Republic. Each participant have been given the Android Mobile device that ARCity app was installed. Each session took about 2 hours, and participants were given instructions on how to use the Andriod phone and ARCity first. Then participants were asked to go around the city centre and to use the app while they were being observed by an evaluator. After the session we have conducted semi-structured interview to evaluate the usefulness and acceptance of the ARcity and followed by SUS questionnaire on the mobile device. Brooke (1996) suggest that System Usability Scale (SUS) is an outstanding choice for usability testing in a wide range of interface technologies because SUS is technology agnostic. Moreover, SUS survey is convenient quick and easy, considering that this quasi-experiment is in an outdoor environment. Finally, SUS survey does not have any cost; hence, the project can continue being a free software system.

SUS survey (BROOKS, 1996), is a questionnaire composed by ten statements with a Likert scale that are scored depending the strength of the agreement. This survey gives a whole view of product's subjective assessment in usability. Final scores for the SUS can range from 0 to 100, where higher scores indicate good usability. SUS questionnaire, in a global view, reflects participants' estimates of the general usability of the interface, without considering the type of interface. The evaluation instrument employed in this evaluation was DroidSurvey android application with System Usability Test loaded in the application. DroidSurvey is part of ISurvey project that allows capturing date directly in smartphones. This application was chosen due to allow applying survey inan convenient way through a mobile application and the facilities for download results to analyses data. The evaluation consisted in bringing the subjects to Freedom Square in Brno Czeck Republic, explaining the purpose of the application and asking the use of the AR City mobile application to perform a touristic route in Brno (see Figure 3). After this activity the subjects filled SUS survey available in the same smartphone, in order to measure the usability and the satisfaction of the subjects. Participants: Seven international students were selected as subjects from Masaryk University. Masaryk University has a strong cooperation with international with foreign institutions worldwide, and as a result there is a high rate of international students attending to this university. Participants were between 18 and 30 years old and had skills handling smartphones in day-to-day basis. With this employed sample, it is assured the subjects meet the characteristics of the target of the application. One criterion applied in the selection was chosen subjects needed to speak English in order to have a full comprehension of the application and the questionnaire. The users will be

tourists that are interested in visit cultural places and want to discover information of these places by themselves. These potential users must be have skills to use smartphone characteristics like: installing new applications from internet, entering input data and using GPS (Global Positioning System) features. Results are reported in terms of usefulness and benefits of using augmented reality mobile application. We asked our participants to comments of usefulness and beliefs of the ARCity application. The great majority of the subjects (86%) mentioned that they have found the application as useful (86%) and they will benefit of using it in contrast to (14%) that they reported that the ARCity does not benefit them to learn. The main findings for the SUS survey applied to AR City! Application are displayed in Figure 4 and 5. The main value obtained for SUS test to the application was 71.79. According to Sauro, above 68, the SUS score is considered above average. Observational study and post-test interview revealed some interesting finding. There were some areas of difficulties that participants were facing whilst using the AR City application. Broadly, they were related to an outdoor setting, in particular related to sun light and reading text on mobile screen.

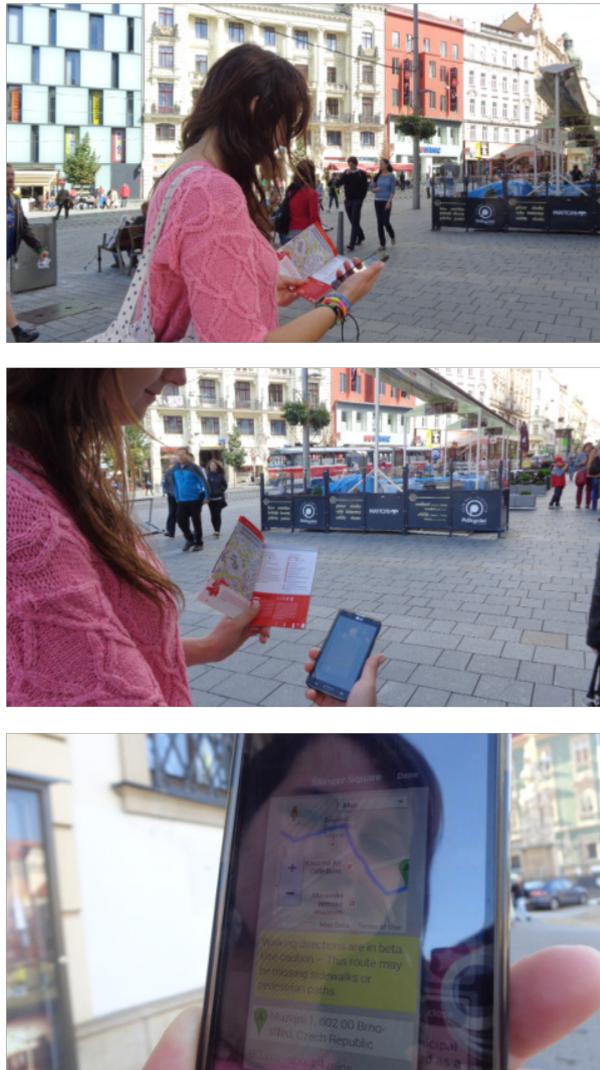


Figure 3. Mobile application to perform a touristic route in Brno

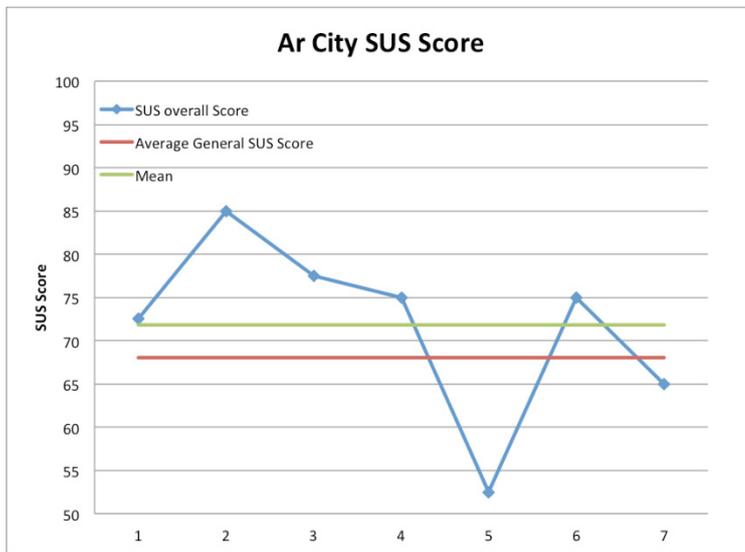


Figure 4. Graphic with the results of AR City evaluation using SUS Survey to measure usability

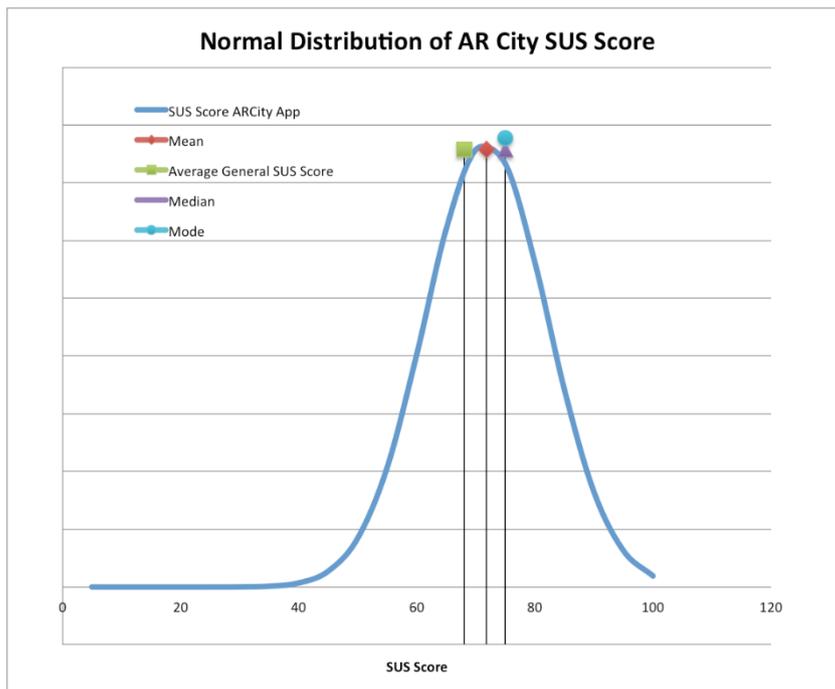


Figure 5. Normal Distribution of results of AR City! evaluation applying SUS survey

Conclusion

The purpose of this project to outline a research project that was conducted to investigate and unravel a potential of augment reality for contextual learning. We gathered a number of general requirements using diary-based method also thematically presented by adapting Leichtenstern and Andre (2008) pervasive computing usage model in order to outline themes considering: environmental, social, and technical context, assisting us to devise a list of general requirements. The ARCity mobile application is developed based on these requirements, and presented as a proof of concept facilitating a contextual and cultural learning using mobile augmented reality technologies.

The results gathered in different dimension to have demonstrated that potential users of this type of application would accept and use in their touristic experiences. Moreover, this kind of systems would encourage people to visit unusual touristic places by themselves because, with the use of augmented reality and location based systems. These features provide further oportunities to get in touch with the environment and at the same time enhancing the onsite tourist experience. In this project through requirement gathering and the results obtained from the evaluation, we are propping some design gudilines that could be used in other similar projects. We outline some general design gudilines (DG) as follows:

DG 1. Guiding interactions through real world object and metaphor

User interface elements such as buttons and navigation objects should follow real world metaphor. For example if real word object located on the left provide on screen user interface elements that enable users to navigate to left accordingly.

DG 2. Provide contextual notifications and feedback

Notifications and feedbacks must be relevant to context and location of the object that users are interacting. Users should be able to turn off the notifications option at anytime.

DG 3. Provide alternative interaction mechanisim for guesture for on screen and off screen objects

User interaface elements such as buttons and navigation object may not be visible in diffe-
rent light and weather confition, in this situation users should be ale to interact with the system using an alternative mechansiism such as voice recognition. In addition, user may find it difficult to find an object that's positioned off screen, which visual or audible cues should be provided in this situation.

DG4. Provide comprehensible and clear instructions in advance for application that incorporate user motion for interaction

Users' safety should come first and also if application relies on motion for interactions, this factor should be communicated to users from the beginning of the application and also to be hinted through notifications throughout the motion interaction. Further testing of motion interaction need to be conducted in different context and location the users may use the application to ensure users safety is not compromised whilst using AR application.

Design guidelines have been outlined above are devised in the context of this project and for development of cultural heritage application, however we can envisage these guidelines to be extend and used in other domain, for example for science and healthcare learning applications using augmented reality technologies.

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A Comunicação Social, enquanto campo do conhecimento pertencente à área das Ciências Sociais Aplicadas, dispõe de contínuos esforços no sentido de estabelecer e compreender os fenômenos científicos comunicacionais sob uma perspectiva inter e transdisciplinar. Assim, o foco científico da publicação mira a complexidade das relações entre ciência e tecnologia e os seus impactos cognitivos no ser humano e na sociedade.

A proposta é acompanhar e compreender cientificamente os caminhos trilhados pela evolução tecnológica no campo da Comunicação Social, construindo ferramentas teórico-metodológicas nas pesquisas na área, se adaptando também aos instrumentos de verificação desenvolvidos em outras áreas do conhecimento – em especial, na Ciência Cognitiva.

É, portanto, um campo de profunda investigação científica, de ação e métodos transdisciplinares, para avançar na compreensão de como as informações são absorvidas, transmitidas e processadas pelo sistema sensorial e pelo conjunto mente/cérebro do ser humano

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