Masters Program in Geospatial Technologies

Improving the user knowledge and user experience by using Augmented Reality in a Smart City context

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IMPROVING THE USER KNOWLEDGE AND USER EXPERIENCE BY USING AUGMENTED REALITY IN A SMART CITY CONTEXT

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ABSTRACT

The idea of *Virtuality* is not new, as research on visualization and simulation dates back to the early use of ink and paper sketches for alternative design comparisons. As the technology has advanced so the way of visualizing simulations as well, but the progress is slow due to difficulties in creating workable simulations models and effectively providing them to the users (Simpson, 2001).

Augmented Reality (AR) and Virtual Reality (VR), the evolving technologies that has been haunting the tech industry, receiving excessive attention from the media and growing tremendously are redefining the way we interact, communicate and work together (Shamalinia, 2017). From consumer application to manufacturers these technologies are used in different sectors providing huge benefits through several applications.

In this work, we demonstrate the potentials of AR techniques in a smart city context. Initially we present an overview of the state of the art software and technology for AR in different domains of smart cities, and outline considerations from a user study about the effectiveness and user performance of AR technique: real environment with augmented information, everything in the context of a smart city. The evaluation results from the participants show promising results, providing opportunities for improvements and implementation in smart cities.

KEYWORDS

Augmented Reality

Geographical Information Systems

Smart City

Virtual Reality

ACRONYMS

AHMD – Advance Helmet Mounted Display

ARCHEOGUIDE – Augmented Reality based Cultural Heritage on-site guide

AR – Augmented Reality

AR UJI – Augmented Reality UJI

CT – computerized tomography

DVN – Direct Visual navigation

HMDs – Head Mounted Displays

IMAX – Image Maximum

LW – Land Warrior

MAR – Mobile Augmented Reality

MR – Mixed Reality

MMG – Multi media Guides

PDAs – Personal Digital Assistants

POIs – Point of Interests

SAFE – Smart Augmented Field for Emergency

UJI – Universitat Jaume I

VR – Virtual Reality

VRML – Virtual Reality Modeling Language

2D – Two Dimensional

3D – Three Dimensional

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1. INTRODUCTION

1.1 Background

A smart city uses technological infrastructure in every aspect of our lives in order to provide solutions to the citizens to make their life easier (Musa, 2016). The way of communication of information is changing with the advancement in technology, which is a basic strategy of Smart Cities for transforming the city infrastructure and services with Information and communication technologies (ICT), as the driving force for changing the way smart cities compete (Bakici, Almirall, & Wareham, 2013). Comprehensively a city cannot be considered of being smart unless technology enhanced, ICT driven spatial enabled solutions are implemented for better urban performance contributing to smart operations of cities (Roche, Nabian, Kloeckl, & Ratti, 2012). The implementation of smart city is the optimization of the urban system with the use of new generation information technology, making the system more consummate, smart, coordinated and developed, while improving the livelihood of the people enhancing their intelligence and live harmoniously (Lv, Yin, Zhang, Song, & Chen, 2016). The usage of mobile applications has become essential for the cities to become smart city, with the rapidly evolving mobile technology.

As the technology has advanced so has the way of visualizing simulations and information. Virtual Reality and Augmented Reality are great examples of such visualization methods which is booming in this digital era, either by being immersed in simulated virtual environment or adding new dimension of interaction between digital devices and the real world. Both methods have something similar, though slightly different and equally significant in their own ways providing experiences and interaction being detached or blending together with the real world, making real and virtual alike. The process of replacing and supplementing the real world according to the needs, is what makes these methods more desirable and increasingly popular. From consumer application to manufacturers these technologies are used in different sectors providing huge benefits through several applications. Major achievement in emergence of low cost or freely available headsets has made possible the creation of such virtual exhibition within the reach of many with even modest budget (Monaghan, O'Sullivan, O'Connor, Kelly, Kazmierczak and Comer, 2011).

"Augmented Reality" the term coined by researcher Tom Caudell, at Boeing in 1990, for guiding factory workers with improved diagrams and marking devices (Caudell & Mizell, 1992). Augmented reality has an ability to layer digital information to a real world environment through a camera, creating a Mixed Reality (MR) (Milgram & Kishino, 1994), with the intent of supplementing useful information. Advancement in mobile technologies and accessibility of online applications has made possible for AR system to provide service without restraining individuals' whereabouts to an especially equipped area (Alem, Tecchia, & Huang, 2011), adding a layer of information whenever desired, having potential to revolutionize the way of presenting information to the people (de Sá, Antin, Shamma, & Churchill, 2011). The year 2017 have seen significant advancement in mobile devices as apple announced its support to advanced Augmented Reality with its A11 bionic neural engine and Apple's ARKit (Apple, 2017), while google partnering with the tech giant Samsung to bring Google's new ARCore framework extending the strength of Android into AR market (Statt, 2017). The investment made by these two tech giants in AR inevitably prove to be a game changer for not only retail, but also for travel and hospitality (Bloom, 2017).

1.2 Problem Statements

Navigation, an ability to travel to preferred location from the current location is crucial for adaptation in a foreign place (Moore Sohlberg, Fickas, Lemoncello, & Hung, 2009). Mobile maps and travel guides has been popular among the people for identification of places, acquiring information and many more. Google maps, the best illustration of technology enhanced life, as it is used far more than just for navigation, more as a facilitator for exploration of new places apart from driving directions powered by google, the best search engine of all times (O'leary, 2017). There are four types of functionality partially or fully incorporated within a mobile applications for navigation and travel (P. Kourouthanassis, Boletsis, Bardaki, & Chasanidou, 2015).

i. Navigation Services, for routing users from current location to preferred location.
ii. Content based services, for information related to user's current requisite.
iii. Social and communication Service, for liaison between traveler and service provider.
iv. Commercial Services, for mobile purchases and reservations.

These properties metaphorically provides travel experiences, insisting the user into more simulated environment rather than interaction with the physical world, where users are immersed in acquiring and requesting digital content or information, paying less attention to the surrounding. Although users shell out 3G and google maps, it takes a while to be accustomed with the surrounding. There are numerous times when a five minutes' walk to the destination had taken 25 minutes to reach (Entwistle, 2016) which is inevitable in a foreign place. Furthermore, the case worsen when language proves a barrier, with no possible way to be assured of the anticipated destination and ending in constant dilemma. Digital information received at the individual's physical point of view offers opportunities to access prompts and directions when needed (Cobb & Sharkey, 2007) providing a proper synchronization of real world and content specific information. The advent of Mobile Augmented Reality (MAR) has provided an opportunity to deliver information of the destinations in a much easier and simpler way rather than checking online sources, maps and travel guides (Yovcheva, Buhalis, & Gatzidis, 2013). Moreover, AR can help foreigners or tourists to become familiar with unknown places in an enjoyable and educational manner (Herbst, Braun, McCall, & Broll, 2008). In a nutshell, AR can influence people in receiving information of the surrounding in a simple manner just by viewing it with a camera, making it useful technology for smart cities.

1.3 Aim and Objectives

The aim and objectives of the research are outlined below:

1.3.1 Aim

- The aim of the research is to investigate the use of Augmented Reality to improve user knowledge and experience of a smart city.

1.3.2 Objectives

- Give an insight of AR applications in various fields in smart city context.
- To identify the potentials of AR applications to know user's surroundings.
- Develop a prototype AR application for efficient and effective visualization of information.
- Investigate the performance, satisfaction and efficiency of AR applications over Google Map.

1.4 Research Aspects

1.4.1 Research Question

- How is the trend of AR in searching information?
- Does the use of AR ease searching landmarks and information effectively and efficiently than a 2D map system?
- Can AR be the supplement for 2D maps?

1.4.2 Research Structure

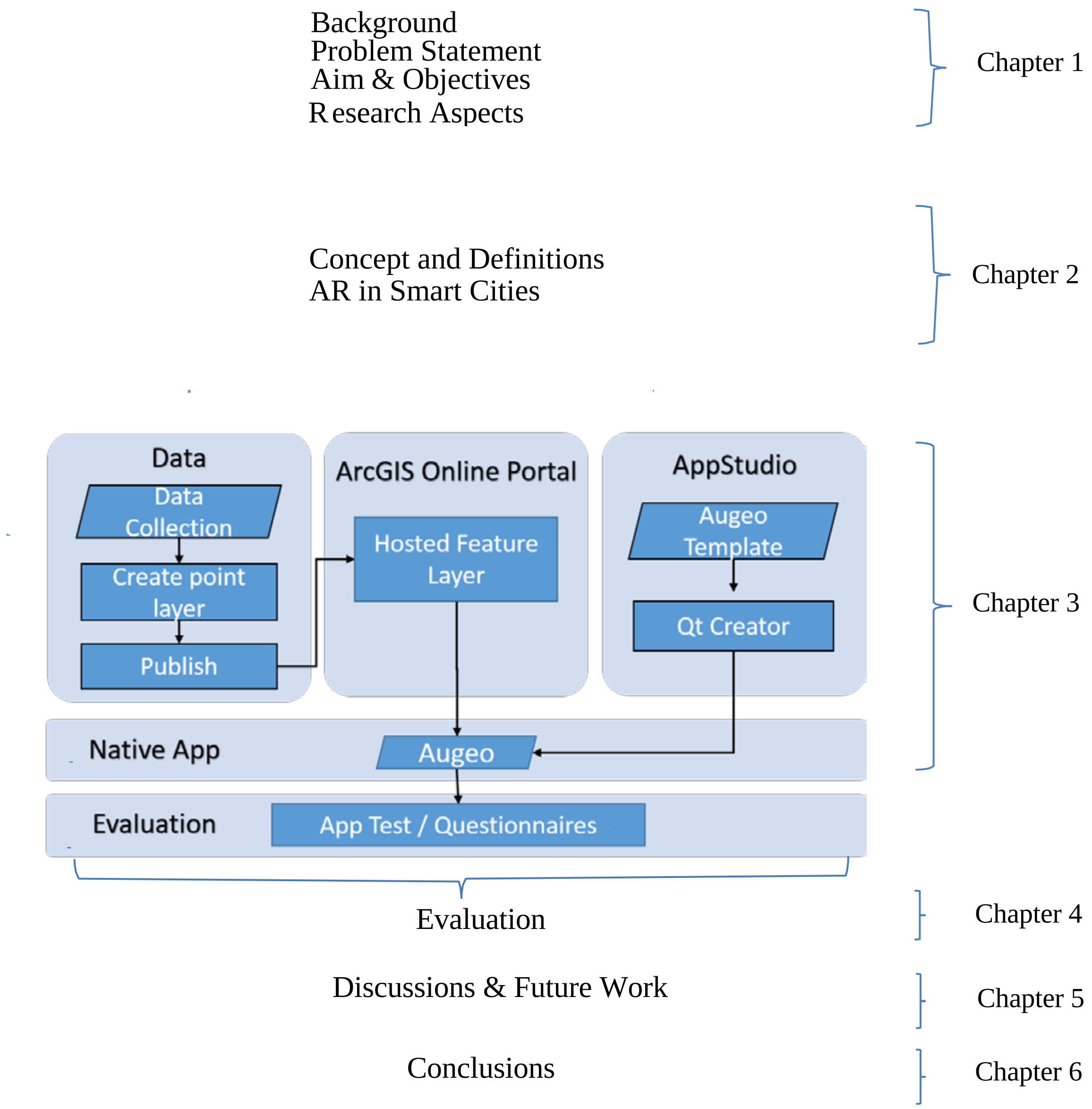


Figure 1: Struture of Thesis

2. THEORETICAL FRAMEWORK

2.1 Concept and Definitions

2.1.1 Augmented Reality

Augmented reality is a technology that layers computer-generated enhancements atop an existing reality in order to make it more meaningful through the ability to interact with it (Augment, 2015). The Wikipedia defines AR as a live, direct or indirect view of a physical, real-world environment whose elements are augmented (or supplemented) by computer-generated sensory input such as sound, video, graphics or GPS data. Janin, Mizell, & Caudell (1993) have defined AR with the use of HMDs, limiting AR to specific technologies. In order to broaden the vision beyond this definition Azuma et al. (2001) defined AR as systems having following characteristics: 1) combines real and virtual; 2) interactive in real time; and 3) registered in 3-D, allowing other technologies, such as mobile technologies, monitor based interfaces, monocular systems to overlay virtual objects on top of real world. Today, AR application uses the camera in the mobile devices producing live view of the real world in combination with relevant, context appropriate information such as text, videos, pictures, etc.

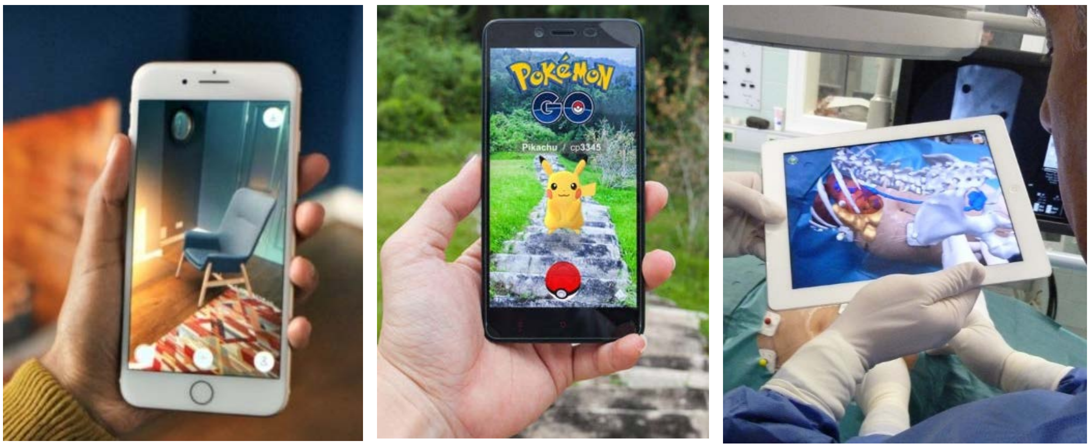


Figure 2: Example of AR Views: a virtual armchair in real home (IKEA), Pokemon Go *(Photo: iStock.com/Lord_Kuernyus)*, AR in Surgery *(Photo: atenkrotos.com)*

There are lots of applications and systems in the market that provides AR functionality, making it difficult to classify and name it. Some are related with the physical real world and other with the abstract, virtual imagery world. Sometimes it’s even difficult to figure whether it’s an AR, as often AR is defined as VR with a transparent Head

Mounted Displays (HMDs) (Zlatanova, 2002). In general the concept is to mix reality with virtual reality including information and overlay over the real world through HMDs such as they seem apparent as one environment. The virtual objects reacts accordingly with the movement of the camera as it is registered with respect to the real world, which is also the main issue of AR (Zlatanova, 2002).

2.1.2 Reality Virtuality continuum

Similar underlying technologies providing enhanced experience with full entertainment is what makes people confuse about AR and VR, considering both technologies as the same (William, 2017). This confusion can be unveiled by the Reality Virtuality Continuum proposed by Milgram in 1994 (Figure 3).

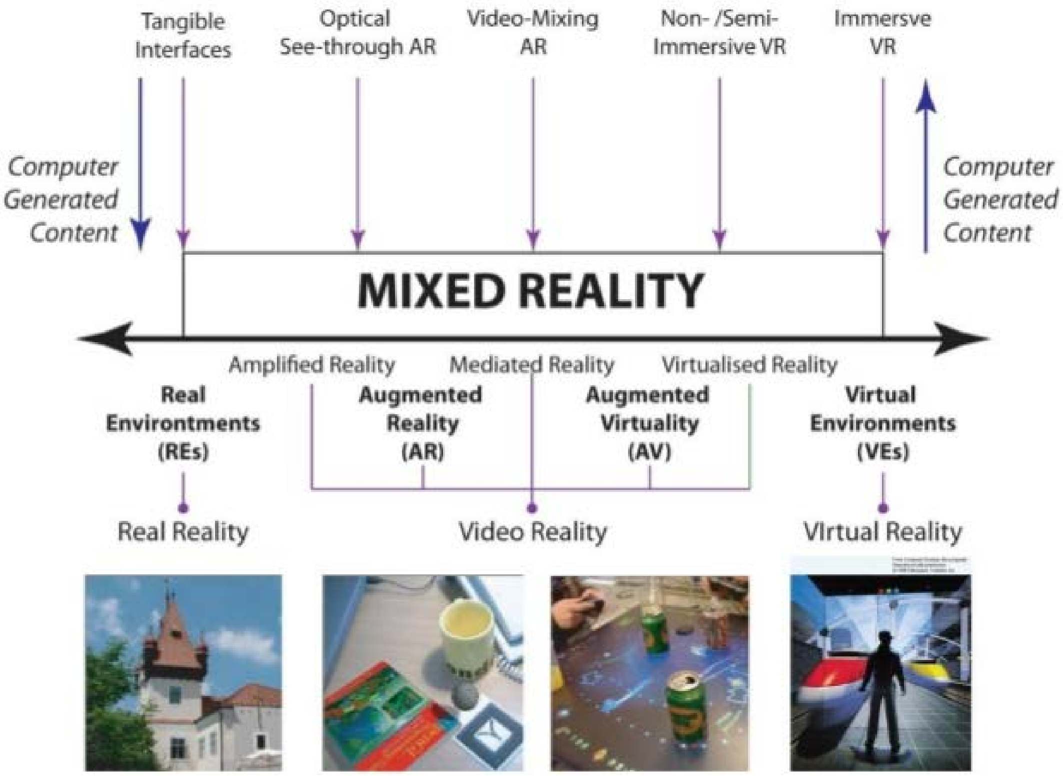


Figure 3: Reality-Virtuality (RV) Continuum (Milgram, Takemura, Ustimi, & Kishino, 1994).

Milgram et al. (1994) introduced the Reality-Virtuality continuum (Figure 3) which defines Mixed Reality and identified range of variations of technology-altered forms of reality which corresponds to augmented and virtual reality technologies of today. If the real world is at one end of the continuum than the virtual world is at the other end, then AR is the space closer to the real world. The closer the system towards Virtual world, more increase in computer generated content; hence reduction in real world elements.

The diagram portrays the relationship of AR, VR, AV and MR with the real and virtual world for which it became a base for discussions, classifications and comparisons between these technologies.

2.1.3 Virtual Reality

Virtual reality (VR) is an artificial, computer-generated simulation or recreation of a real life environment or situation, immersing the user by making them feel like they are experiencing the simulated reality firsthand, primarily by stimulating their vision and hearing (Augment, 2015). Virtual Reality, the term coined by Jaron Lanier, founder of VPL Research (1989) (Blanchard et al., 1990) , initially referred to “Immersive Virtual Reality” where the user becomes fully immersed in the virtual 3D world (Giraldi et al., 2003). The ultimate virtual reality is realized when the user is fully immersed into the virtual world with special VR headset and controllers to interact and get the information. Virtually simulating an environment is replicating its aspect more accurately in order to provide an illusion of the reality, where the degree of immersive vary (Giraldi, Silva, & Oliveria, 2003).VR can be classified into two different types: non immersive and immersive. The former is a computer based simulations of the real world, whereas immersive VR adds dimensions of immersion, interactivity and user involvement (Freina & Ott, 2015) to the former , completely detaching the user from their surrounding into simulated reality with a head mounted device replacing the actual world (Byrne, 2017).

It is typically achieved through a HMD like Oculus Rift, Samsung Gear VR etc. and is possible through a coding language known as VRML (Virtual Reality Modeling Language) creating a series of images, and specifying what types of interactions are possible for them. It is used prominently in two different ways (William, 2017):

i. To create and enhance an imaginary reality for gaming, entertainment, and play (Such as video and computer games, or 3D movies, head mounted display).

ii. To enhance training for real life environments by creating a simulation of reality where people can practice beforehand (Such as flight simulators for pilots).

2.1.4 Mixed Reality

Wikipedia defines MR as “The hybrid reality, where real and virtual worlds merge to produce new environments and visualisations where physical and digital objects co-exist and interact in real time. MR not only takes place in real and virtual world, rather is a mix of reality and virtual reality, encompassing both augmented reality and augmented virtuality." Instead of just a layer on top of real world, MR brings the ability to combine digitally rendered objects into the real environment. The best example is the Microsoft’s HoloLens, a self-contained holographic container, engaging with the digital content and interacting with holograms in the real world (Microsoft, 2017).

2.1.5 Augmented Virtuality

Augmented Virtuality is the ability to explore interactively a virtual representation obtained from the real world. The Wikipedia defines it as a “subcategory of Mixed Reality which merges the real world objects into the virtual world”. Mostly this can be achieved through streaming video from physical spaces (e.g. via webcam) or by using 3D digitization of physical objects (Wikipedia). The videos or real objects are draped into virtual objects, somewhat making the virtual world seem like real world to some extent, maintaining the flexibility of the virtual world (Zlatanova, 2002).

An example of Augmented Virtuality is, an aircraft maintenance engineer who visualizes a real time model of the airplane engine in flight, as it occurs on a screen with real world elements that are physically apart. Other popular experiences of Augmented Virtuality are playing a game on a Nintendo wii or watching an IMAX movie.

2.2 AR in Smart City

Application of AR technology within the smart city services are not commonly available and mostly in piloting phase (Pokric, Krco, & Pokric, 2014). Moreover some applications have been developed on mobile devices, enhancing the experience in smart city allowing considerable public participation (Bertacchini et al., 2014). With the development in technologies, AR applications have been started to use in various smart city applications (Ozcan, Arslan, Ilkyaz, & Karaarslan, 2017). In this section, examples of augmented reality applications in various domains of Smart City is discussed.

AR has become more and more popular in research sector as a method of advanced visualization. Numerous research papers are published in some international journal and conferences. According to the Scopus Database (October, 2017) on Augmented Reality, number of paper published on various domains of AR is shown below in Figure 4.

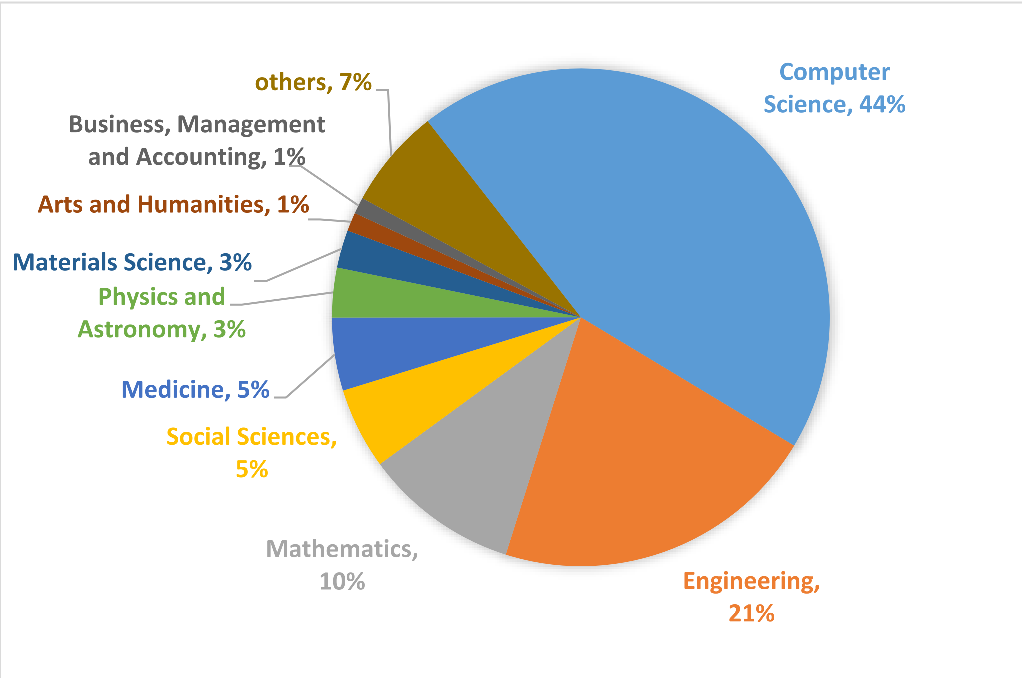


Figure 4: "Augmented Reality" – number of papers per subject area.

Figure 3 shows the number of selected papers on various subject areas based on the search reports of Scopus Database on AR, as of October 2017. The figure shows that majority of papers area in the Computer Science area with 44%, and other majorities are in Engineering 21% and Mathematics 10%, as most of the work is related with computer programming or computer based environments.

Nevertheless, a significant number of researches are done on social science, about 5%. Also we can see that 5% is related to medicine, 3% in physics and astronomy, 2 % in Art and humanities. Furthermore, 7% is categorized to “other” section referring to Decision Sciences, Environmental Science, Earth and Planetary Sciences, etc.

Therefore, as a useful visualization technique AR technology can be used to solve smart city problems creating new solutions in many domains such as medical, robotics, military, Navigation, traveling, education, entertainment, marketing, tourism, urban planning, manufacturing, product assembly and repair, architecture etc. which are discussed below.

2.2.1 Medical

AR can be used in wide range of medical practice ranging from pre-operative imaging training and education to image guided surgery, as it provides surgeon with necessary view of the internal anatomy and improved sensory perception, reducing the risk of an operation. The need for visualizing the patient and the medical information on the same physical space is why researchers thrive for AR, as it provides the real time visualization of heterogeneous data required for guided surgery. Roberts et al. (1986) executed the first medical augmented reality system superimposing preoperative computerized tomography (CT) data in proper position, scale and orientation. Medical students use the AR technology to practice surgery in a controlled environment. Medical AR provided a useful tool for medical guidance, training, education, procedure and workflow. AR helps to project anatomical information or image guided surgical landmarks onto the patient (J. Der Lee, Huang, Lax, Lee, & Wu, 2011; J. Der Lee, Lee, Hsieh, Wu, & Lee, 2015) which provides image guidance during surgical procedures decreasing risks associated with long procedure times (Cheung, Wedlake, Moore, Pautler, & Peters, 2010). Such operation support system with augmented reality technology reduces the cognitive load of doctors in the operation room (Tano et al., 2012)

2.2.2 Military

A battlefield is a place of chaos and uncertainty where timely information decides the life and death of soldiers. Augmented annotated information in the real battlefield scenario with HMDs can be used with AR (Urban, 2000). The liteye company has researched and used HMDs for military purposes. Through innovative progress in AR the US Army's Land Warrior (LW) Program introduced an intelligent agent based decision support system on LW's wearable computer providing perspective view in the weapon sight (Hicks, Flanagan, Petrov, & Stoyen, 2003). The helicopter night vision system was developed by Canada's Institute for Aerospace Research (NRC-IAR) using AR to expand the operational envelope of rotor craft and enhance pilots' ability to navigate in degraded visual conditions (Yu, Jin, Luo, Lai, & Huang, 2009).

Not only AR has been used for assisting military personnel's in the battlefield, but also provide training solution with Advance Helmet Mounted Display (AHMD) by overlaying actual , augmented and simulated visible environment (Sisodia, Riser, Bayer, & McGuire, 2006). Champney et al. (2016) promoted discussion concerning the military training tradeoffs with mixed reality about its usability, simulator fidelity and immersion.

2.2.3 Tourism

Tourism is another blasting industry where the use of AR has an imperative role in redefining the concept of traditional tourism through advance technologies. This change in discovering reality with conceivable overlay of computerized improvements containing intuitive data has significantly made tourism more intelligent and exciting. Vlahakis et al. (2001) presented the first Augmented Reality based Cultural Heritage on-site guide (ARCHEOGUIDE), to provide tourists with the reconstructed view of the cultural site and archaeological information related to it. Similarly Park, Nam, & Shi (2006) used AR to provide an immersive experience of the historical scene reflecting needs of tourists improving the quality of cultural tour. Cinotti et al. (2004) developed a wearable device called WHYRE, a context aware Multi media Guides (MMG) to turn museums and archaeological sites into communicating machines. The success to this project created a milestone and perceived as novel approach with a significant market potential. In order to minimize the time to visit a large scale museum or exhibition, Lee & Park (2007) proposed an AR based guidance system for guiding the user with the relative orientation , distance and visual cue to find the particular exhibits and multimedia information on that exhibit.

To embroil more tourists, simple, inexpensive, and sustainable AR application emerged due to development in hand held devices. Zoellner, Keil, Drevensek, & Wuest (2009) presented the Cultural Heritage Layers, an approach to visualize historic media like paintings, photographs of buildings and historic scene from the archives and seamlessly superimpose on reality at the right spot. With the evolving technology and development in more commercial mobile applications, the delivery in the content of AR has been lot easier and superior (Kounavis, Kasimati, & Zamani, 2012). There has been lots of development in mobile AR applications of guided tour to enhance perception of the reality (Renda et al., 2012; Kawazoe & Hemmi, 2014; Tahyudin, Surya Saputra, & Haviluddin, 2016; Shang et al., 2017).

2.2.4 Navigation

Navigation in simulated environments has been tried and tested and is still in research phase. Turunen, Lankila, Pyssysalo, & Roning (2000) introduced a personal navigation system in urban areas with mobile augmented reality terminals based on 3G cellular network. Mobile outdoor navigation systems for pedestrians and electronic tourist guides are already available on PDAs (Narzt et al., 2003). Z. Hu & Uchimura (2002) proposed a new concept of Direct Visual navigation (DVN), superimposing virtual direction indicators and traffic information into real road scene providing efficient guidance to the drivers. But this was limited to mobile based navigation system and the driver had to gaze away from the road in order to visualize the navigation information, leading too much of the accidents. Thus, Nakatsura, Yokokohji, Eto, & Yoshikawa (2003) proposed image overlay on optical see through display on the front glass of the vehicle for navigation minimizing accident caused due to shifting of gaze from the road to the console. Increasing technologies and creation of gadgets for aiding drivers with navigations are a sort of distractions (Levy, Dascalu, & Jr., 2005). The role of any navigation system is to support the driver to reach the destinations, the main thing to consider is how these navigation system impacts in achieving the driving goals. AR navigation provide better and faster support route decision making and are visually more demanding (Kim & Wohn, 2011).

2.2.5 Education

Research shows that Education with AR has proven to be extremely useful in increasing the students' motivation in learning process (T. Y. Liu & Chu, 2010; Jara, Candelas, Puente, & Torres, 2011; Di Serio, Ibáñez, & Kloos, 2013; Bujak et al., 2013; Chang et al., 2014). Imagine the size of the books if all the images were in 3D, it would seem impossible. The ability of supplementing real world objects with virtual objects coexisting in same space (Azuma et al., 2001) with seamless combination of virtual objects with the real world has made it possible. The addition of missing information with virtual objects to real scenes (El Sayed, Zayed, & Sharawy, 2011), interaction with 2D and 3D virtual objects in the real world (Chen & Tsai, 2012) and superimposing the invisible phenomena in physics such as electromagnetic forces (Ibáñez, Di Serio, Villarán, & Delgado Kloos, 2014) has improved academic achievements and increased content understanding resulting to long term memory retention (Radu, 2014).

2.2.6 Disaster Response

Disaster management is a complex process with lots of uncertainties, incomplete information and requires instant decision and action. During disaster response situation, first responders require support and guidance for performing relief operations. AR can be a specific solution where computer generated information is superimposed over the real world providing sufficient information and guidance required by the first responders to initiate the relief operation. Several systems are already addressing the use of AR in support of emergency response such as Augmented reality system for earthquake disaster response (Leebmann, 2004), which overlays different invisible disaster-relevant information (e.g. people buried by rubble , simulations of damages and measures) and overlay it with real environment. Brunetti, Croatti, Ricci, & Viroli (2015) presented a wearable AR collaborative system, Smart Augmented Field for Emergency (SAFE) integrated with intelligent agents and multi-agent systems with the purpose of helping first responders and operators involved in rescue mission. Providing first responders with information and skills to respond to health, security and managerial issues are key factors to be pursued during an emergency response. AR mobile interfaces helps in enhancing training efficacy for on-site crisis preparedness activities (Sebillo, Vitiello, Paolino, & Ginige, 2016).

2.2.7 Games

Augmented Reality in games produces a real time 3D display effect by superimposing virtual information on to the real world. The main motivation of such games are to involve teenagers more into sports and exercise (Zhao, Chen, Wang, & Zhang, 2016). AR related games are not only for amusement but for various fields such as education, medical treatment, tourism and training. Unlike VR gaming which requires a separate room or confined area to create an immersive environment, AR gaming expands the playing field, making the game more interesting taking advantage of the diverse world. Also, AR games typically uses mobile devices while VR games requires special headsets. Introduced in July 2016, Pokémon Go, a mobile location based social game, is by far the most popular AR game involving physical activity of gamer in the real world with potential and documented health benefit.

In a nutshell, Smart cities uses ICT for enriching the quality and performance of mobile devices in the city, where AR can provide new solutions to various domains of smart city. Speaking of AR, it is mostly used in mobile devices such as laptops, smart phones, and tablets to change how the real world and digital images, graphics intersect and interact. The use of AR in asset repair system providing pinpointing repair areas has allowed field technicians to quickly and efficiently query and update repair and customer-based information. Sightseeing has never been more interesting and fun than before, as the ability to augment facts and figures and relevant information as an overlay on the display of smartphone enhancing tourism. Navigation applications are probably the best fit of AR providing user the best experience of driving a vehicle with route over the view of the car. Apart from training, AR assists military personnel's in the battlefield by displaying critical data as well as valuable information on the HMD. Medical students use AR technology to practice surgery in a controlled environment and also reduce the risk of an operation providing surgeon with improved sensory perception. Thus, with the help of AR a city is smarter than ever.

3. RESEARCH METHODOLOGY

3.1 Overview

It’s not exaggeration to say map apps like Google maps and Apple maps for searching places and facilities around, is the most popular trend. With the rise of AR and VR in the tech industry, what will be the impact of these technologies to the trending map apps? This study intends to provide an evaluation on the use of AR for finding places in town and information regarding it as a substitution to web mapping services such as Google maps. The preliminary idea is to develop an AR app of a place and evaluate from a group of users. A qualitative approach is used where the user is opt to view both the models and presented to answer questionnaires which is later used for evaluation. The study was conducted among fresh International students with less knowledge of the university environment. The applications features the facilities and services available in the Universitat Jaume I (UJI), Castellon, Spain. The user are presented with the AR application to perform certain tasks usually done with other 2D apps of their choice. Later the users are offered with questionnaires related to the functioning of the apps and the willingness of the users to use the app in near future with improvements of their desire.

3.1.1 Study Area

Figure 5: Study Area

The study area is the province of Universitat Jaume I of castellon, Spain, a proactive public higher education and research center, welcoming huge number of national and international students every year. It is the northernmost university in the Valencian Community offering 31 undergraduate degrees, 47 official postgraduate master's degrees, 16 UJI-specific master's degrees and 39 specialization courses approximating 14,000 students. According to the university, nearly 600 foreign students i.e. around 10% of the total students were welcomed in the academic year 2015. This provided a good platform for the testing the application as many fresh students are new to the University with less knowledge about the surroundings.

3.2 Methodology

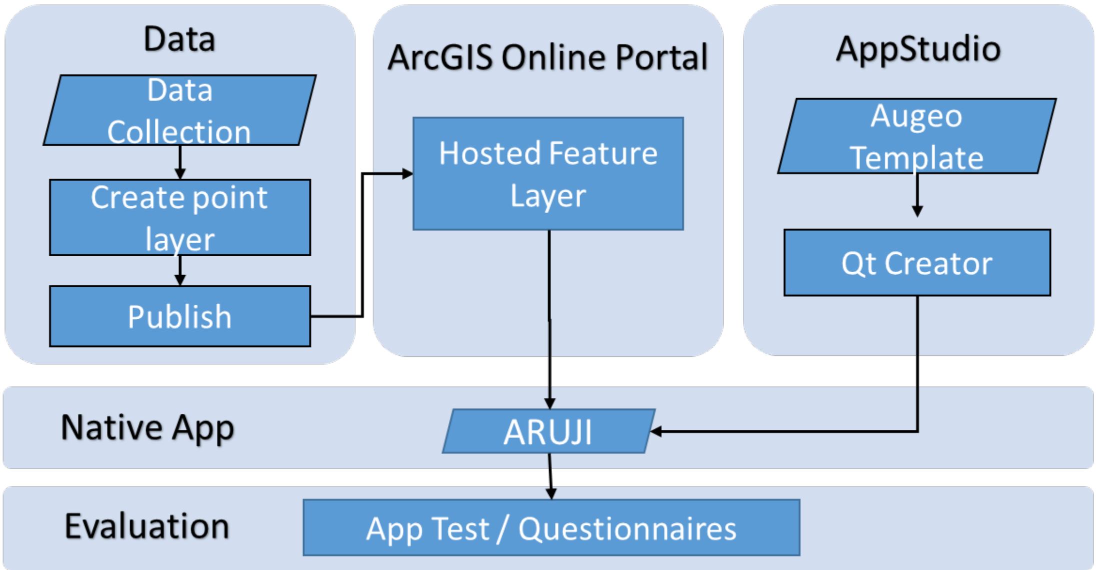


Figure 6: Methodology for the Research

3.2.1 Data

The data required for the project is acquired from Smart UJI Campus project, University Jaume I, Castellon, Spain. For AR, point layer with relevant information are published in the ArcGIS online portal as hosted feature layer, which is further accessed by the native app Augmented Reality UJI (ARUJI).

3.2.2 Software

The AR UJI app is build using the AppStudio for ArcGIS, a tool for building cross-platform native apps, based on AuGeo template which is edited with Qt creator for customization and configuration of the apps.

AppStudio for ArcGIS, a tool that converts maps into beautiful mobile apps for various platform such as Mac, iOS, Android, Window and Linux and publish them into the app stores. Depending upon the type of license user are able to customize and configure the apps. Basic License gives user, the ability to build apps using configurable app templates, whereas with Standard license, user can create custom apps using own developer skills to extend the configurable templates app and distribute within the enterprise. A normal ArcGIS Online account holder is provisioned with the basic license only.

Qt Creator, a cross-platform integrated development environment, included in AppStudio for ArcGIS for modifying, editing or creating new apps. Qt creator uses the Qt Modeling Language (QML), a user interface specification and programming language where JavaScript is used as a scripting language.

AuGeo template, a template provided by the Esri labs as noncommercial offerings for developers to dive into Augmented Reality, so any developer with a standard license can use the source code to embed the AuGeo functionality in their own applications.

ArcGIS Online, a collaborative web GIS allowing user to use, create and share maps, layers, data, apps, scenes, and analytics. It is accessible through web browsers and mobile device through an organizational account or a public account. This project uses an organizational account with standard license for AppStudio for creation, updation and maintenance of the app.

3.3 Mobile app (ARUJI)

With the standard license of ArcGIS Online account, a cross platform Augmented Reality application is created configuring the AuGeo template with custom settings and displays.

3.3.1 System overview

AR UJI is a Native app, a prototype of an AR guiding app for the students and visitors around the university of Jaume I and available in android devices as an unsigned application. Generally, the system provides basic functionality of a location based Augmented Reality application using ArcGIS point feature layers in order to easily locate assets around the user location through the lenses of the mobile’s camera. Basically it displays information about the point of interest as a pop up with icons or media designating the POI and some quick info. Figure 8 shows the interface of the application with an interactive popup in front of the building with the tentative distance to the building.

This application has been developed using the AuGeo template, a noncommercial platform into Augmented Reality by Esri Labs for developers, built on AppStudio for ArcGIS which uses QML for modifying and editing the functionalities of AuGeo. The point of interest are GIS point shapefile with information as its attributes and is accessed from the ArcGIS online. The point shapefile is displayed as a pop up on top the camera with information signifying the real world infrastructures.

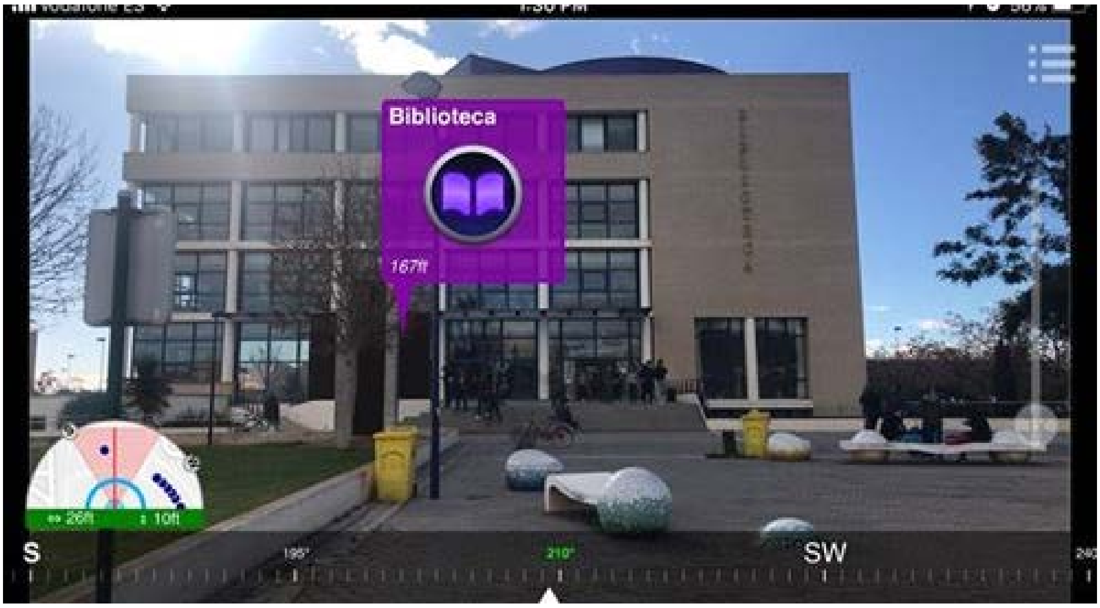


Figure 7: AR UJI app in action.

3.3.2 Functionality

Initially, the ARUJI functions with the download of hosted feature layer, a collections of point features of all the buildings and services available in UJI, from the ArcGIS online portal. Once the feature is downloaded it can also be used in offline mode. The application prepares for the compass calibration of the mobile and determines the user location which is the most essential requirement determining the accuracy of the application. The higher the compass calibration and accurate location determination, more the accuracy of the location of the point features. The services available in UJI are categorized in the following as seen in the table. Each categories are further divide to its possible elements as available inside the University.

Table 1. Categories and its elements for using in the AR UJI app.

Categories	Elements
Food	Café, Restaurant, Canteen, Vending Machines
Bank	Bank, ATM
Shop	Retail store, Printing, Optics
Transport	Bus Stop, Bicicas Station
Health Service	Dental Clinic, Clinic
Building	Department, Office, Library, Info Centre, Gallery

The main window of the application supports two distinct types of functionality. First, users can receive more information the displayed POIs by selecting in the screen of their mobile device (such as opening hours, phone number, etc.). Second, users can navigate to the 2D map view mode by click the circular radar at the bottom left corner of the screen for navigational directions to the selected POI.

Naturally, marker based and geo based AR are prone to "occlusion problem", i.e. the real world as well as the AR contents itself may visually conceal the display AR contents obscuring valuable information (Yovcheva, Buhalis, & Gatzidis, 2013; Kourouthanassis, Boletsis and Lekakos, 2013). Indeed the AR UJI app is no exception, with possibility of displaying POI icons on top of each other for distant POIs. However, these occlusion problems can be solved to some extent with extra options provided to the user. The user can configure the maximum extent for displaying the POIs from the user location, excluding POIs far away causing extra noise in the display screen. Furthermore, the user can zoom in the camera for precise display of POIs. In addition, user can select or unselect the properties that is displayed in the data popups, reducing the size of the popups.

3.3.3 Architecture

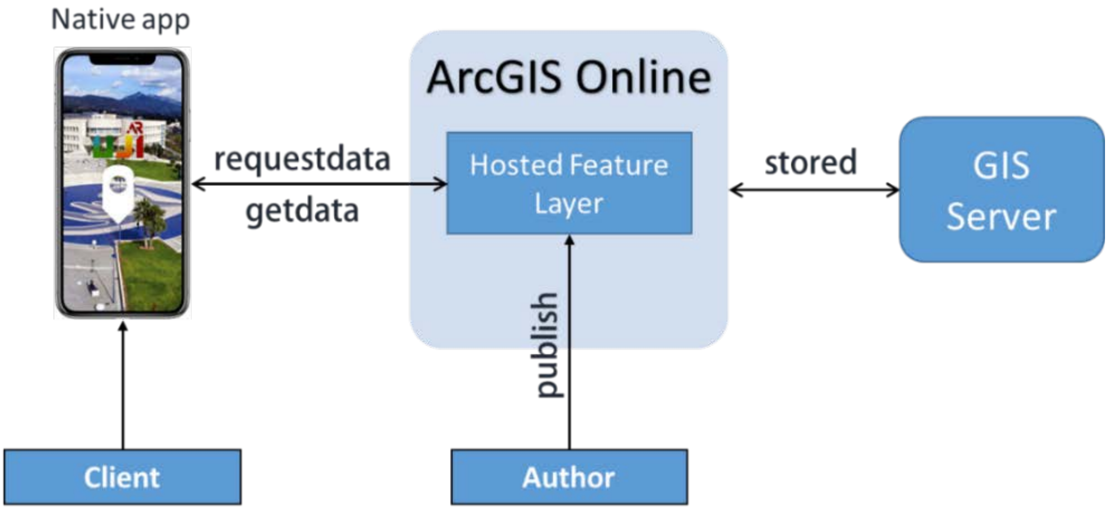


Figure 8: The architecture of AR UJI

According to the system architecture Figure 9, when the user open the AR UJI application, it request data from the hosted services published or shared in ArcGIS Online platform by the provider of the app. The ArcGIS online platform validates the request and provides access to data to be downloaded in the form of ArcGIS point feature layers, which visualizes the content into an augmented reality environment in the mobile device. The point feature layer contains all the information about the feature, ensuring its availability in offline mode. The basic difference in using the inbuilt AuGeo app from the AuGeo template and ARUJI app is that, in AuGEO users need to sign in using the ArcGIS account and set all the variables after signing in and download the data required to run the application. But, the ARUJI app runs without user to sign in to the ArcGIS account as the credentials are stored within the application. Moreover the variables are set to default use, appropriate for the users with the data already downloaded for use.

4. EVALUATION

4.1 Study Design

The research was design to response the research questions in the section 1.4.1. Initially, a prototype of AR guided application is tested among a group of international exchange students. The problems and difficulties associated with the spatial knowledge and skills of the students were being acknowledged in the unfamiliar urban dynamics and existing issues with the linguistic difference, in order to provide a solution with AR guided maps service. The study is not completely a usability testing, but lies in between a research and a usability study, to provide a better solution to the confronted problem amongst the international exchange students. This study is designed to focuses mainly on improving user knowledge and experience on AR apps for guiding and providing information in a smart city. First the trend in using of AR guided applications over other map services apps is determined with questionnaires related to user's knowledge and experience in AR applications. Later propose a prototype of AR application for use in the vicinity of the University for Users Experience with AR.

The study comprise of independent variable as the type of View (2D Map view and the AR view) and dependent variables as Effectiveness, Efficiency and Satisfaction. As the study included only one independent variable, a basic design was approached (Lazar, Feng, & Hochheiser, 2010) with two conditions in the experiment (with and without AR view), i.e. experimenting with Map View and AR View. The effectiveness was determined by the successful completion of the task with and without using the ARUJI application on a basis of Likert scale 1-5 (1: Not at all, 5: Very much). The Efficiency was determined by the time taken for successfully completion of the task with Map View (Google Maps) and AR View (ARUJI). For this two task where defined, to be performed with AR UJI app and another 2D map app (majority of Google Maps). The satisfaction in using the ARUJI app in this study was determined directly as well as indirectly through the questionnaire. In the indirect determination of satisfaction the questionnaire was classified into five factors namely, ease of Use (successfulness), Clarity of information, controllability, helpfulness and fun. The questionnaires also involved a more direct approach in the sense that the respondents were asked explicitly about the comfortability and satisfaction in using the ARUJI app compared to other mapping apps.

4.2 User Sampling

A convenient sampling methodology was adopted for inviting prospective users of AR UJI. The participants consisted of 20 random individuals and groups from different countries who were new to the University, and having experience in using mobile applications, in order to avoid biasness and ensure credibility of the results. Table 2 provides the information of the demographics of the participants. The sample comprised of equally distributed men and women. Furthermore, the participants were selected from Bachelors and Master Degree program with bachelor level students between 19-25 years old and Master level students above 26 years old. All the participants had good experience using mobile applications and were too much into technologies.

Table 2: Sample Demographics

Dimension	Value	Total	Percentage %
Gender	Male	10	50
	Female	10	50
Age	< 18	1	5
	19 – 25	9	45
	26 – 35	10	50
	35 +	0	0
Education	University Graduate	10	50
	Post Graduate	10	50

4.3 Materials

The study was mostly conducted with an Android-based Samsung Galaxy Tab S 8.4 WiFi SM-T700 16GB model, running Android 6.0.1 Marshmallow with a Samsung Exynos Octa-Core CPU processors: 1.9Ghz Quad-Core ARM Cortex-A15, 1.3Ghz Quad-Core ARM Cortex-A7 and having ARM Mali-T628 MP6 GPU graphics card and 3GB LPDDR3 RAM. The Tab is inbuilt with 8 megapixels main camera and a resolution of 3264 x 2448 pixels. The Tab is well equipped with sensors like accelerometer, compass, and gyroscope sensors and supports A-GPS, GeoTagging, GLONASS, and BeiDou GPS signals which is prime essential for the application to run smoothly.

4.4 Procedure

Initially, the objectives of the study was explained to the randomly approached participants, and requested to download the application through the link provided during the explanation. As the app was created to support only in android platform, participants were verified whether they owned an Android device. In case they owned device other than Android, a Samsung Galaxy Tab was given for testing purpose. The participants were requested to download the app to their mobile phone and instructed to use the application. The users were given a task to locate services and facilities around them with their choice of app and later perform the same task with the AR UJI app. As a final request, the participants were asked to fill in the questionnaires for evaluation to measure the performance, usability, controllability, comfortability, clarity in information, helpfulness and satisfaction in using the application.

The user were allowed to use the application in the vicinity of the university and requested to use their preferred application for searching places around them (such as restaurants, café, departments, etc.) and later instructed to use the AR UJI application to do the same. A questionnaire form was prepared with google forms and presented to the users for their experiences using the AR UJI app. The questionnaires were developed using the 5 point Likert scale, for better understandability and the results can be easily quantifiable. The 5 point Likert scales was preferred as possible over a binary choice (Yes/No) or a 3 point Likert scale, as it provides only direction rather than providing level of perception. Also the 10 point Likert scale was not favorable for participants, creating difficulties in choosing the options giving insignificant results (Dillman, Smyth, & Christian, 2014). The questionnaires are segmented into 3 phases as follows:

Table 3: Categories of the questionnaires.

Categories	**Description**
General statistics	This section includes general questions related to the user such as age, gender, qualification, technology interest, etc.

Knowledge about the AR technologies	This section of questionnaires are to measure user's knowledge in these technologies and the existing apps being used by the users relating to these technologies.
Proposed AR app	This section includes questions related to the experience of the AR app developed for the experiment. Users are prompted with various questions regarding the easiness, difficulties, understanding, controls, information provided, discomforts and helpfulness of the proposed system.

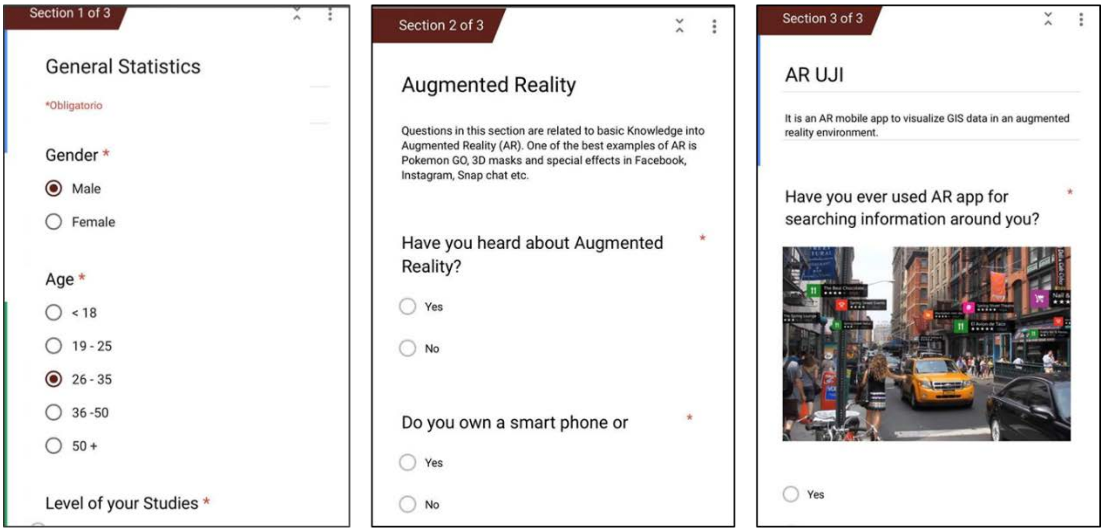


Figure 9: Sample of the questionnaire for discovering user profile and evaluation of the app.

Also, a simple and easy tasks was assigned to every participants in order to use the application for better understanding of the research and easement in answering the questionnaires. The task was let to perform using ARUJI app and another map service app (Google Maps) and the time taken for each performance was recorded for evaluating the efficiency of the application.

Table 4: Description of the Task

Tasks	Description
Task 1	Find the Name of the building and its opening hours in front of you.
Task 2	Find the nearest coffee shop from your location.

4.3 Results

After the app AR UJI was developed for Android, its performance, usability, effectiveness, and satisfaction were tested among some international students in UJI for better and unbiased outcome. The results were derived from the responses to the questionnaires. Almost all of the participants relied on 2D apps like google maps, apple maps and Maps.me for searching and navigating around, with maximum adhering to Google Maps with 63% (Figure 10). Only few participants have used AR for searching information. It was found that, 95 % of the participants never heard of AR apps similar to AR UJI, providing augmented reality solutions for searching places and information.

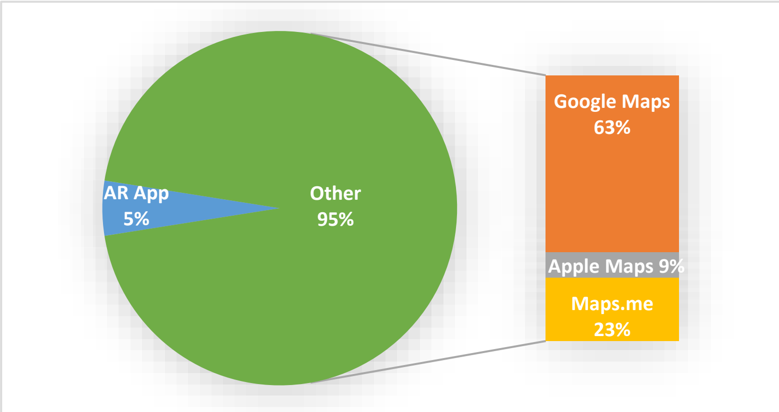


Figure 10: Apps used by the participants for searching information.

Remaining 5% participants have used Google AR translate for translating languages on boards while searching for places. This portrays that there has been lack of knowledge about such AR apps, related to navigation and tour guide. Figure 11 shows the graph of AR applications used by the participants which are mostly related to entertainment and education domain, which can be justified from the graph in Figure 12, which shows the reason for using such AR app.

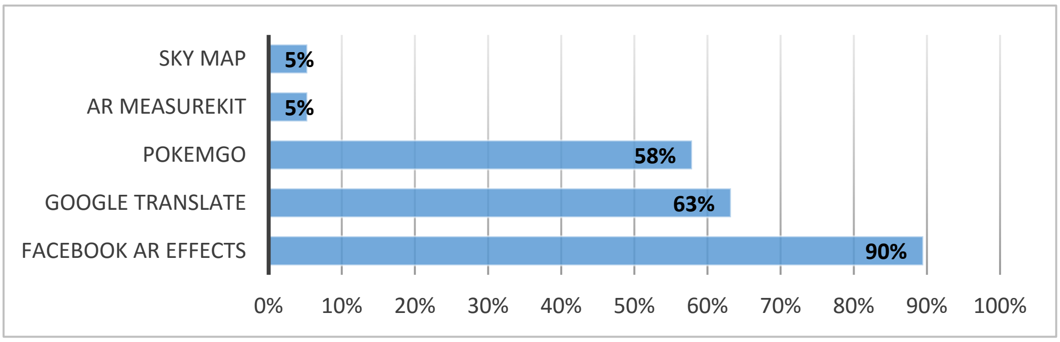


Figure 11: AR apps used by participants

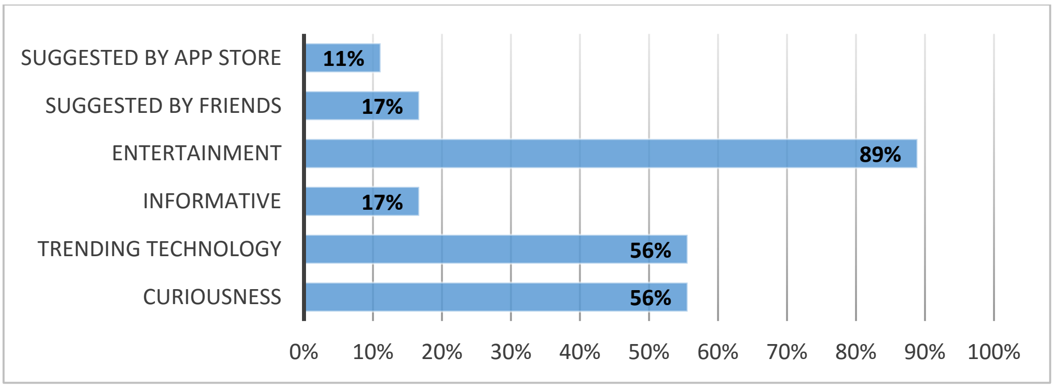


Figure 12: Reasons for using AR app.

More than 80% of the participants used AR applications, as it was fun and full of entertainment. Half of them were using it due to curiosity and for being a technology in trend. Least of them, about 17% used AR apps to gain information. It is possible that AR solutions has not yet been well presented in these scenarios in order to see its popularity in such sectors. This facts can be further supported by the graph in Figure 13, which shows the search trends in AR applications over past few years. The search trends for AR apps had been in a decreasing trend for many years until it hyped drastically after the lunch of Pokemon GO in July 6th 2016, which remained for some months and declined to its previous state. But the interest in AR apps can be seen increasingly progressive and picked up the pace after the release of ARKit for iOS and Google ARCore near the end of 2017.

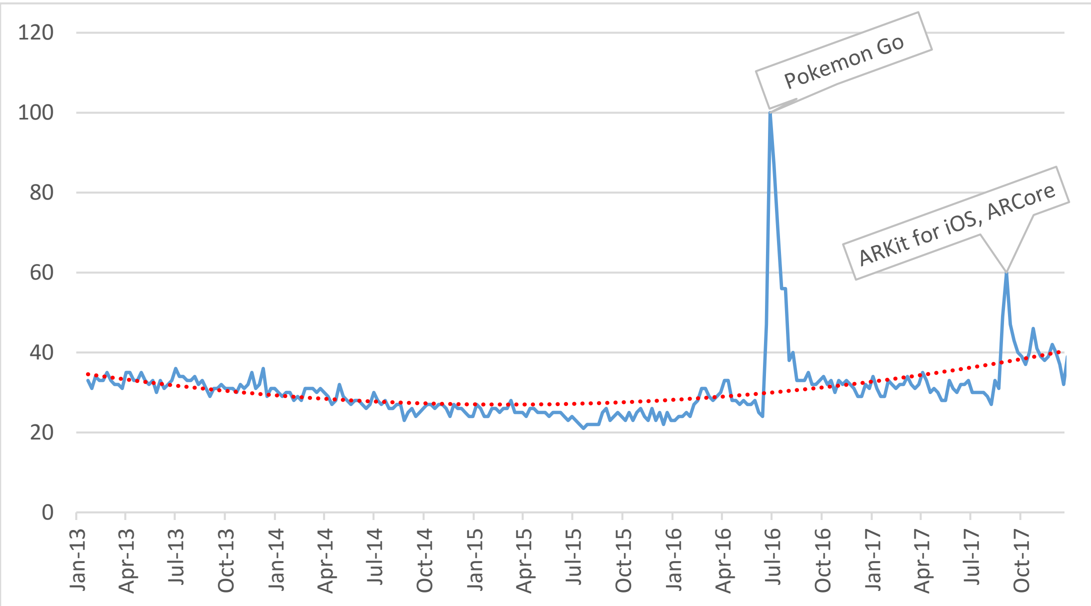


Figure 13: Google Search Trends of Augmented Reality apps (*Source: Google Trends*)

This clearly depicts the reason for non interest in AR apps among users, due to lack of AR developing platforms and its support in mobile devices. The recent development in AR sector with its support in mobile devices has led in the rise of interest in AR apps, but is still limited to specific domains such as entertainment. According to Mozenix (2018), Pokemon Go, an AR game application generated a revenue greater than the value of entire VR software market in its first three month after its launch. Thus with the recent launches of ARKit and ARCore, 2018 will be a momentous year for AR technology, becoming a mainstream commercial application.

4.3.1 Effectiveness

The effectiveness of the application measured from the successful completion of both the tasks (Task1 & Task 2) in Map View and AR View was 100%. All the participants were able to complete the task without any problems. The participants found the ARView more effective in finding information and services of nearby surroundings more than the Map View, with some participants commenting AR View to be more fun and astonishing experience in map sector. The participants have valued, more the interface with information in the popups providing better perceptions of the surrounding vicinity compared to that conveyed by Map View. The Table 5 below signifies that almost every participants found AR View to be very much effective and helpful in locating services nearby.

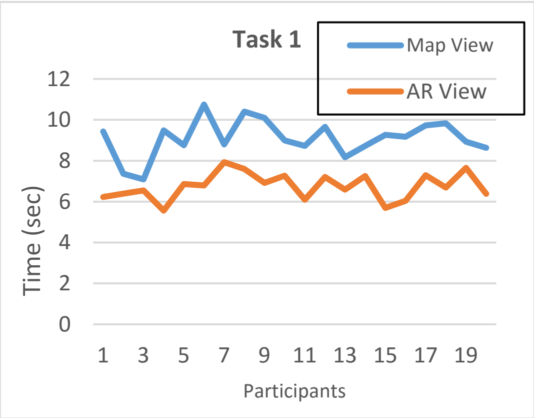
Table 5: Effectiveness of ARView in compared to MView using a Likert scale: 1–5 (1: Not at all, 5: Very much).

	Question	Median	Average
Q	How effective did you find ARUJI over other 2D Map view apps?	5	4.65

4.3.2 Efficiency

The time taken to complete the tasks using the Map View and AR View ca be seen in the graph (Figure 14) below. For Task 1, it can be indubitably said that AR View is more efficient than the Map View. However, Task 2 illustrates few fluctuations where

Map View proves more efficient. This is due to the nature of the task and users ability of fast reaction to the question. As it was observed during the experiment, for task 2,



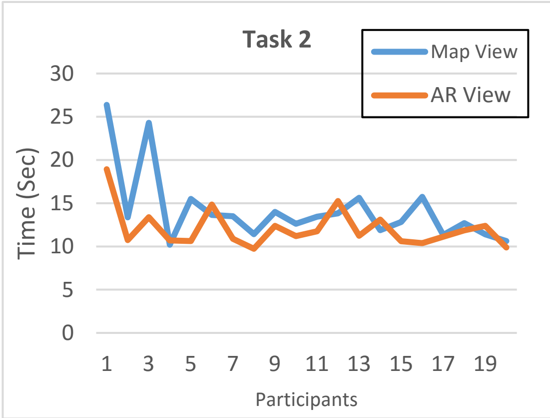


Figure 14: Time taken to complete the tasks using Map View and AR view.

Almost every participants were typing the word "nearest coffee shop", "coffee "or "cafe", for finding the nearest café in the university. The efficacy in typing and with the concise keyword might have been the reason behind the efficiency of Map View in some observations. The average time taken by AR View to complete both the task is slightly less than that of the Map View. The difference in completion of both task with AR view and Map View is around 2 secs (Table 6). Hence, AR View is slightly efficient than the Map View in locating services around the surrounding area.

Table 6: Average time taken to complete both tasks by the participants

	Task 1	**Task 2**
Map View	9.1 sec	14.21 sec
AR View	6.75 sec	12.05 sec

4.3.3 Satisfaction

The satisfaction of the users were evaluated in two phase, indirectly and directly. Firstly, the participants were asked questions related to ease of use, controllability, clarity, and successful maneuver of the application that served as an indirect means of evaluating satisfaction.

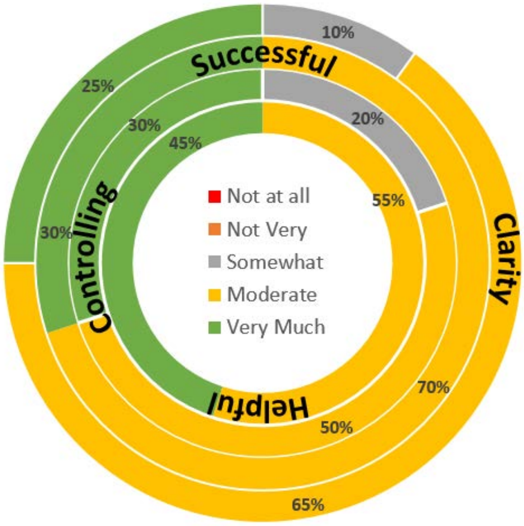


Figure 15: Effectiveness and performance of the app

In Figure 15, we can see that almost all the participants are somewhat clear about the information displayed in the app, and able to control and successfully get information from the app, with minority of the participants i.e. 20% trying a bit hard in controlling and finding problem in clarity of the displayed information. This is mainly due to fast movement of the mobile and relative slow processing of the mobile, which effects in the oscillations of the popups causing difficulty in controlling the app. The secret to perfect control lies in the slow and steady handling of the mobile.

The graph (Figure 15) depicts that participants were able to successfully complete the assigned task effectively where more than half participants are positive towards its usefulness and the rest agrees it to be totally helpful for searching places and services around. While using the application, the expression of the users were positive and everyone was enjoying the application with satisfaction.

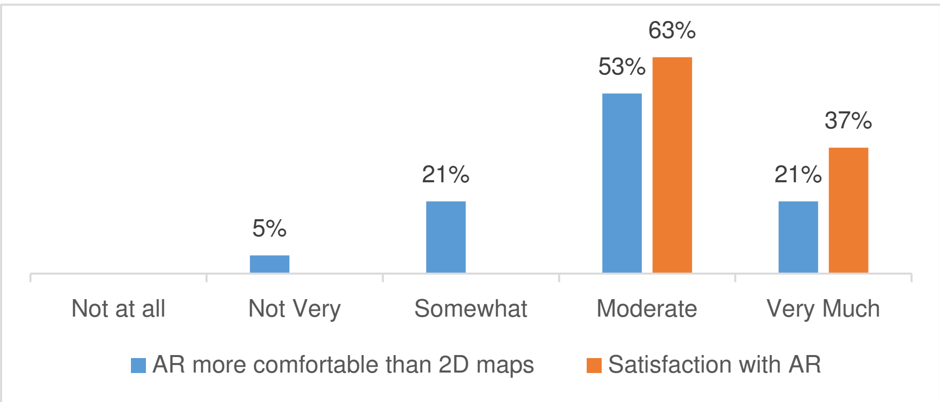


Figure 16: Comfortability and Satisfaction of using AR compared to other 2D apps

The second evaluation of users satisfaction involved more direct questionnaires related to comfortability and satisfaction in compared to Map View. With the proposed AR application acquiring information and finding place around was lot easier and efficient for which almost every users were satisfied with majority of 63% and remaining 37% being very much satisfied. Points of interest are displayed as pins with interactive information through phone's camera which is informative and beneficial in searching place of interest around.

Furthermore, the bar chart in Figure 16 shows that 74 % of the students were comfortable using the proposed AR UJI app with no difficulties in controlling the app, with 21% being somewhat comfortable about its controllability, compared to their usual 2D apps. The reason behind is the frequent crashing of the application due to low memory space. Better the technical specification of the smart phone smoother the performance of the application. Students found the app to be more entertaining, informative, and efficient for searching information in the vicinity, with one fourth participants willing to use the app for further searches and three fourth participants to use the app after slight updates and fixes (Figure 17). Every participants were enjoying and perceiving information through the use of the AR app which depicts that there has been lack of awareness about the true potential of AR apps.

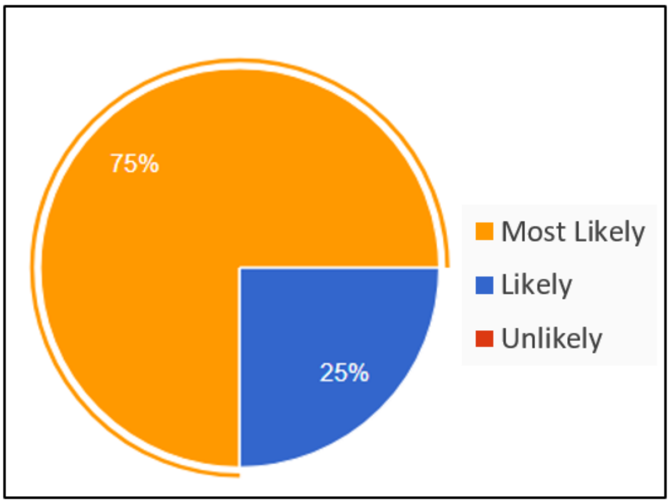


Figure 17: Preference of using the app in near future by the participants.

5. DISCUSSION AND FUTURE WORK

5.1 Methodology

During the debriefing of the applications, participants expressed their problems faced during finding location and departments inside the university due to language problem and most of the name of the location were hard to find in google maps as they were referred with codes. Many stated that they had ended up being into another department while using 2D map service and almost felt lost during no internet connectivity.

The task assigned was simple and less time consuming, as longer and difficult task would have uninterested the participants. Also, finding participants willing to volunteer for the experiment was a challenging and tough task. Many participants found the app to be more fun, intuitive and informative. Additional, the offline mode of the application was appraised by the participants, during low internet connectivity. However, the application was seen crashing in some mobiles due to low memory and low processing. But in new version mobile with high memory and processing speed, the app was running perfectly well. In few mobile, the location accuracy was inaccurate due to inaccurate compass and location calibration which was eliminated with recalibration of the compass and location.

5.2 Limitations

As with any empirical study, there are some limitations entangled with it. Foremost, the results are based on self-report study, as it involved participants to fill in questionnaires regarding their user experience of the ARUJI App. A Qualitative method with detailed interview and observation of the participants could have been more prolific and factual. Secondly, a convenience sampling technique was selected, as it was fast, inexpensive, and easier to recruit participants and proximity to the researcher. Thus subjected to limitations in generalization and inference, resulting to low external validity of the research. Thirdly, the research was conducted among students between 18 to 35 years age group (Millennials age group), as they are familiar with communications, media, and digital technologies.

Moreover, the app has been developed for Android devices. Thus it doesn’t support iOS and windows devices. Furthermore, the application supports augmentation of only point features, adhering to the same old 2D map view for routing (linear features) to the destinations, as the AuGeo template only supports point features.

5.3 Interpretation of Results

With the Augmented Reality application AR UJI, viewers are provided information on top of the real world. They affirmed that the application is far better and quick to know the information of the building with just a popup in front decreasing the search time and eliminating confusion. The results would have been more pledging with more participants for the experiment.

The majority of the user were not aware of such applications, and were curious in using the application. Some respondent were confused about AR and few have never heard of it. But were clarified when given an example of Pokemon Go. This depicts that Pokemon Go has brought limelight to AR applications and has yet to come to the mainstream for which user’s knowledge and experience in AR has to improve. It was observed that participants were enjoying the ARUJI app and some even wanted to suggest the app to their newly arrived friends for better interaction with the university surroundings. During the testing of the ARUJI app, it was found that the virtual information on top of the real world is more effective than a 2D map for those who are in a state of confusion due to disorientation in 2D map. Also, in times of urgency, the ARUJI app can prove to be more efficient than the 2D map, for locating information and services in the surroundings. Majority of the participants were totally satisfied with the applications and affirmed to use the applications with some minor update.

5.4 Future Work

In future, a within group design and quantitative methods such as in depth interviews and observations can be implemented to get more statistically and intriguing results, since the findings are based on self-reported data. Also, the study was only focused for international students. However, during the debriefing session it was noticed that other students were equally in need of such applications, as mostly relied on the perspective drawing of the University for searching departments and location of classes. At times, the occlusion problems lingered, where the facilities were close to each other, despite of defining less distance for displaying data. More works can be done on self-adjusting popups for minimizing the occlusion problems in future work. The application is supported only in Android devices, which can be extended to work with iOS and windows mobile. In addition, an extra social media feature like rating the point of interest, can be integrated in the app for recommendations to other users making it more interactive. More work can be done on AR navigation replacing the same old 2D navigation system, to provide full AR experience to the users. Nevertheless, the ARUJI app is only supported inside the periphery of the university, which can be further extended to the city in future.

6. CONCLUSIONS

In this work, we have shown how augmented reality can help us in a smart city context. Thus, some studies related to AR we conducted, lead us to explore new methods to support and offer better decisions tools for the citizens in a city context. Moreover, we demonstrate that users are open to use new technologies such as augmented reality in order to perform operations that usually were carried out by using a typical mapping mobile app such as Google or Apple Maps, engaging the user the entire time and making less aware of the surroundings.

This research presented AR UJI, a functional mobile augmented reality guide, supporting users on the move by displaying information about the surrounding point of interests when user selects on the screen of their smart devices. With the AR app, users more interact with real world along with the information on top of it. The outcomes of the study shows that there has been an increasing trend in AR applications due to recent development of AR platform like ARKit and ARCore. The user's interest in using ARUJI application also leads to similar conclusion. The results obtained from the user study answer our research question about the use of Augmented Reality for searching places and services around with ease. The participants were able to perform the assigned task successfully and comfortably. Most participants found AR to be fun, trending technology and informative. Those who were aware of this technology had only used it for entertainment purpose as opposed to education and information, which clearly specify lack of awareness regarding this technology in other domains. This conclusion is further supported by the fact, that the user not knowing about similar AR apps in the market. In a nutshell, AR with smart mobiles has the potential to increase smartness in users, making them more compatible and eligible to live in smart cities.

REFERENCES

Alem, L., Tecchia, F., & Huang, W. (2011). Recent Trends of Mobile Collaborative Augmented Reality Systems. *Recent Trends of Mobile Collaborative Augmented Reality Systems*, 135–148. https://doi.org/10.1007/978-1-4419-9845-3

Apple. (2017). The future is here: iPhone X Press Release. Retrieved January 4, 2018, from https://www.apple.com/newsroom/2017/09/the-future-is-here-iphone-x/

Augment. (2015). Virtual Reality vs. Augmented Reality (Augment News). Retrieved November 29, 2017, from http://www.augment.com/blog/virtual-reality-vs-augmented-reality/

Azuma, R., Baillot, Y., Behringer, R., Feiner, S., Julier, S., & MacIntyre, B. (2001). Recent advances in augmented reality. *IEEE Computer Graphics and Applications*, *21*(6), 34–47. https://doi.org/10.1109/38.963459

Bakici, T., Almirall, E., & Wareham, J. (2013). A Smart City Initiative: The Case of Barcelona. *Journal of the Knowledge Economy*, *4*(2), 135–148. https://doi.org/10.1007/s13132-012-0084-9

Bertacchini, F., Bilotta, E., Carini, M., Gabriele, L., Pantano, P., & Tavernise, A. (2014). Learning in the smart city: A virtual and augmented museum devoted to chaos theory. In *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* (Vol. 7697 LNCS, pp. 261–270). https://doi.org/10.1007/978-3-662-43454-3_27

Blanchard, C., Burgess, S., Harvill, Y., Lanier, J., Lasko, A., Oberman, M., & Teitel, M. (1990). Reality built for two: a virtual reality tool. *ACM SIGGRAPH Computer Graphics, 24*, 35–36. https://doi.org/10.1145/91394.91409

Bloom, A. (2017). Why Augmented Reality Changes Everything. Retrieved January 4, 2018, from https://www.businessoffashion.com/articles/opinion/op-ed-why-augmented-reality-changes-everything

Brunetti, P., Croatti, A., Ricci, A., & Viroli, M. (2015). Smart Augmented Fields for Emergency Operations. *Procedia Computer Science*, *63*(Icth), 392–399. https://doi.org/10.1016/j.procs.2015.08.358

Bujak, K. R., Radu, I., Catrambone, R., MacIntyre, B., Zheng, R., & Golubski, G. (2013). A psychological perspective on augmented reality in the mathematics classroom. *Computers and Education, 68*, 536–544. https://doi.org/10.1016/j.compedu.2013.02.017

Caudell, T. P., & Mizell, D. W. (1992). Augmented reality: an application of heads-up display technology tomanual manufacturing processes. In *Proceedings of the Twenty-Fifth Hawaii International Conference on System Sciences* (Vol. IV, pp. 659–669). https://doi.org/10.1109/HICSS.1992.183317

Champney, R., Salcedo, J. N., Lackey, S. J., Serge, S., & Sinagra, M. (2016). Mixed reality training of military tasks: Comparison of two approaches through reactions from subject matter experts. In *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in*

Bioinformatics) (Vol. 9740, pp. 363–374). https://doi.org/10.1007/978-3-319-39907-2_35

Chang, K. E., Chang, C. T., Hou, H. T., Sung, Y. T., Chao, H. L., & Lee, C. M. (2014). Development and behavioral pattern analysis of a mobile guide system with augmented reality for painting appreciation instruction in an art museum. *Computers and Education*, *71*, 185–197. https://doi.org/10.1016/j.compedu.2013.09.022

Chen, C. M., & Tsai, Y. N. (2012). Interactive augmented reality system for enhancing library instruction in elementary schools. *Computers and Education*, *59*(2), 638–652. https://doi.org/10.1016/j.compedu.2012.03.001

Cheung, C. L., Wedlake, C., Moore, J., Pautler, S. E., & Peters, T. M. (2010). Fused video and ultrasound images for minimally invasive partial nephrectomy: A phantom study. In *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* (Vol. 6363 LNCS, pp. 408–415). https://doi.org/10.1007/978-3-642-15711-0_51

Cinotti, T. S., Nagaraj, R. N. R., Mincolelli, G., Raffa, G., Roffia, L., & Sforza, F. (2004). WHYRE: a context-aware wearable computer for museums and archaeological sites. *Eighth International Symposium on Wearable Computers*, *1*, 3–4. https://doi.org/10.1109/ISWC.2004.49

Cobb, S., & Sharkey, P. (2007). A Decade of Research and Development in Disability, Virtual Reality and Associated Technologies: Review of ICDVRAT 1996−2006. *The International Journal of Virtual Reality*, *6*(2), 51–68.

de Sá, M., Antin, J., Shamma, D., & Churchill, E. F. (2011). Mobile augmented reality: video prototyping. *Proceedings of the 2011 Annual Conference Extended Abstracts on Human Factors in Computing Systems*, 1897–1902. https://doi.org/10.1145/1979742.1979927

Di Serio, Á., Ibáñez, M. B., & Kloos, C. D. (2013). Impact of an augmented reality system on students' motivation for a visual art course. *Computers and Education*, *68*, 585–596. https://doi.org/10.1016/j.compedu.2012.03.002

Dillman, D. A., Smyth, J. D., & Christian, L. M. (2014). *Internet, phone, mail, and mixed mode surveys: The tailored design method*. *BOOK*. https://doi.org/10.4037/ajcc2016979

El Sayed, N. A. M., Zayed, H. H., & Sharawy, M. I. (2011). ARSC: Augmented reality student card An augmented reality solution for the education field. *Computers and Education*, *56*(4), 1045–1061. https://doi.org/10.1016/j.compedu.2010.10.019

Entwistle, J. (2016). 14 problems to overcome during your year abroad. Retrieved January 4, 2018, from https://erasmusu.com/en/erasmus-blog/erasmus-tips/14-problems-to-overcome-during-your-year-abroad-280692

Giraldi, G. ., Silva, R., & Oliveira, J. . (2003). *Introduction to Virtual Reality*.

Herbst, I., Braun, A.-K., McCall, R., & Broll, W. (2008). TimeWarp: interactive time travel with mobile mixed reality game. *In: Proceedings of the 10th International Conference on Human Computer Interaction with Mobile Devices and Services (MobileHCI),* 235–244. https://doi.org/10.1145/1409240.1409266

Hicks, J. D., Flanagan, R. A., Petrov, P. V., & Stoyen, A. D. (2003). Eyekon: Augmented reality for battlefield soldiers. In *Proceedings - 27th Annual NASA Goddard / IEEE Software Engineering Workshop, SEW 2002* (pp. 156–163). https://doi.org/10.1109/SEW.2002.1199462

Hu, Z., & Uchimura, K. (2002). Dynamical road modeling and matching for direct visual navigation. In *Proceedings of IEEE Workshop on Applications of Computer Vision* (Vol. 2002–Janua, pp. 237–241). https://doi.org/10.1109/ACV.2002.1182188

Ibáñez, M. B., Di Serio, Á., Villarán, D., & Delgado Kloos, C. (2014). Experimenting with electromagnetism using augmented reality: Impact on flow student experience and educational effectiveness. *Computers and Education, 71*, 1–13. https://doi.org/10.1016/j.compedu.2013.09.004

Janin, A. L., Mizell, D. W., & Caudell, T. P. (1993). Calibration of head-mounted displays for augmented reality applications. In *Proceedings of the IEEE Virtual Reality Annual International Symposium* (pp. 246–255). https://doi.org/10.1109/VRAIS.1993.380772

Jara, C. A., Candelas, F. A., Puente, S. T., & Torres, F. (2011). Hands-on experiences of undergraduate students in Automatics and Robotics using a virtual and remote laboratory. *Computers and Education, 57*(4), 2451–2461. https://doi.org/10.1016/j.compedu.2011.07.003

Kawazoe, Y., & Hemmi, K. (2014). Mobile Sightseeing and Navigation System with Photograph Superimposition Function: On Return Route Search Methods. In *Proceedings of the 12th International Conference on Advances in Mobile Computing and Multimedia* (pp. 127–131). https://doi.org/10.1145/2684103.2684118

Kim, K. H., & Wohn, K. Y. (2011). Effects on productivity and safety of map and augmented reality navigation paradigms. *IEICE Transactions on Information and Systems, E94–D*(5), 1051–1061. https://doi.org/10.1587/transinf.E94.D.1051

Kounavis, C. D., Kasimati, A. E., & Zamani, E. D. (2012). Enhancing the tourism experience through mobile augmented reality: Challenges and prospects. *International Journal of Engineering Business Management*, *4*(1), 1–6. https://doi.org/10.5772/51644

Kourouthanassis, P., Boletsis, C., Bardaki, C., & Chasanidou, D. (2015). Tourists responses to mobile augmented reality travel guides: The role of emotions on adoption behavior. *Pervasive and Mobile Computing*, *18*, 71–87. https://doi.org/10.1016/j.pmcj.2014.08.009

Kourouthanassis, P. E., Boletsis, C., & Lekakos, G. (2013). Demystifying the design of mobile augmented reality applications. *Multimedia Tools and Applications*, *74*(3), 1045–1066. https://doi.org/10.1007/s11042-013-1710-7

Lazar, J., Feng, J. H. J., & Hochheiser, H. (2010). *Research methods in human-computer interaction*. *Evaluation*. https://doi.org/10.1002/asi.21187

Lee, D. H., & Park, J. (2007). Augmented reality based museum guidance system for selective viewings. In *Proceedings - 2nd Workshop on Digital Media and its Application in Museum and Heritage, DMAMH 2007* (pp. 379–382). https://doi.org/10.1109/DMAMH.2007.4414584

Lee, J.-D., Lee, H.-C., Hsieh, C.-H., Wu, C., & Lee, S. (2015). A Projection-based Medical Augmented Reality System. *Proceedings of the 8th International Symposium on Visual Information Communication and Interaction*, (3), 164–165. https://doi.org/10.1145/2801040.2801065

Lee, J. Der, Huang, C. H., Lax, T. Y., Lee, S. T., & Wu, C. T. (2011). A medical augmented-reality system for image-guided surgery using marker-added ICP. *International Journal of Innovative Computing, Information and Control*, *7*(11), 6523–6539.

Leebmann, J. (2004). AN AUGMENTED REALITY SYSTEM FOR EARTHQUAKE DISASTER RESPONSE. *Virtual Reality*, *35*, 909–914. Retrieved from http://www.isprs.org/proceedings/XXXV/congress/comm3/papers/399.pdf

Levy, M., Dascalu, S. M., & Jr., F. C. H. (2005). ARS VEHO: Augmented Reality System for VEHicle Operation. *Computers and Their Applications*, 282–289. Retrieved from http://www.cse.unr.edu/~dascalus/CATA2005_ML.pdf

Liu, T. Y., & Chu, Y. L. (2010). Using ubiquitous games in an English listening and speaking course: Impact on learning outcomes and motivation. *Computers and Education*, *55*(2), 630–643. https://doi.org/10.1016/j.compedu.2010.02.023

Lv, Z., Yin, T., Zhang, X., Song, H., & Chen, G. (2016). Virtual Reality Smart City Based on WebVRGIS. *IEEE Internet of Things Journal*, *3*(6), 1015–1024. https://doi.org/10.1109/JIOT.2016.2546307

Microsoft. (2017). Microsoft HoloLens | The leader in mixed reality technology. Retrieved January 6, 2018, from https://www.microsoft.com/en-us/hololens

Milgram, P., & Kishino, F. (1994). Taxonomy of mixed reality visual displays. *IEICE Transactions on Information and Systems*, *E77–D*(12), 1321–1329. https://doi.org/10.1.1.102.4646

Milgram, P., Takemura, H., Ustimi, A., & Kishino, F. (1994). Augmented Reality: A class of display on the reality-virtuality continuum. *Telemanipulator and Telepresence Technologies*, *2351*, 282–292.

Moore Sohlberg, M., Fickas, S., Lemoncello, R., & Hung, P. F. (2009). Validation of the activities of community transportation model for individuals with cognitive impairments. *Disability and Rehabilitation*, *31*(11), 887–897. https://doi.org/10.1080/09638280802356260

Mozenix. (2018). Top 5 augmented reality applications 2018. Retrieved February 19, 2018, from https://mozenix.com/2017/10/09/top-5-augmented-reality-trends-2018/

Musa, S. (2016). Smart City Roadmap. *Academia.edu*. Retrieved from https://www.academia.edu/21181336/Smart_City_Roadmap

Nakatsura, T., Yokokohji, Y., Eto, D., & Yoshikawa, T. (2003). Image overlay on optical see-through displays for vehicle navigation. In *Proceedings - 2nd IEEE and ACM International Symposium on Mixed and Augmented Reality, ISMAR 2003* (pp. 286–287). https://doi.org/10.1109/ISMAR.2003.1240723

Narzt, W., Pomberger, G., Ferscha, A., Kolb, D., Müller, R., Wieghardt, J., … Lindinger, C. (2003). Pervasive information acquisition for mobile AR-navigation systems. In *Proceedings - 5th IEEE Workshop on Mobile Computing Systems and Applications, WMCSA 2003* (pp. 13–20). https://doi.org/10.1109/MCSA.2003.1240763

O'leary, D. (2017). Navigation Wars: Google Maps vs Waze vs Apple Maps. Retrieved January 4, 2018, from https://www.androidauthority.com/navigation-wars-google-maps-vs-waze-vs-apple-maps-783994/

Ozcan, U., Arslan, A., Ilkyaz, M., & Karaarslan, E. (2017). An augmented reality application for smart campus urbanization: MSKU campus prototype. In *ICSG 2017 - 5th International Istanbul Smart Grids and Cities Congress and Fair* (pp. 100–104). https://doi.org/10.1109/SGCF.2017.7947610

Park, D., Nam, T.-J., & Shi, C.-K. (2006). Designing an immersive tour experience system for cultural tour sites. In *CHI '06 extended abstracts on Human factors in computing systems - CHI EA '06* (p. 1193). https://doi.org/10.1145/1125451.1125675

Pokric, B., Krco, S., & Pokric, M. (2014). Augmented Reality Based Smart City Services Using Secure IoT Infrastructure. In *2014 28th International Conference on Advanced Information Networking and Applications Workshops* (pp. 803–808). https://doi.org/10.1109/WAINA.2014.127

Radu, I. (2014). Augmented reality in education: A meta-review and cross-media analysis. *Personal and Ubiquitous Computing*, *18*(6), 1533–1543. https://doi.org/10.1007/s00779-013-0747-y

Renda, G., Gigli, S., Amato, A., Venticinque, S., Di Martino, B., & Cappa, F. R. (2012). Mobile devices for the visit of anfiteatro campano in Santa Maria Capua Vetere. In *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* (Vol. 7616 LNCS, pp. 281–290). https://doi.org/10.1007/978-3-642-34234-9_28

Roberts, D. W., Strohbehn, J. W., Hatch, J. F., Murray, W., & Keti 'enberger, H. (1986). A frameless stereotaxic integration of computerized tomographic imaging and the operating microscope. *J Neurosurg*, *65*, 545–549. https://doi.org/10.3171/jns.1986.65.4.0545

Roche, S., Nabian, N., Kloeckl, K., & Ratti, C. (2012). Are " Smart Cities " Smart Enough ? *GSDI World Conference*, 215–236. https://doi.org/10.1080/10630731003597322

Sebillo, M., Vitiello, G., Paolino, L., & Ginige, A. (2016). Training emergency responders through augmented reality mobile interfaces. *Multimedia Tools and Applications*, *75*(16), 9609–9622. https://doi.org/10.1007/s11042-015-2955-0

Shamalinia, S. (2017). Virtual and Augmented Reality Applications in Building Industry. In S. T. Rassia & P. M. Pardalos (Eds.), *Smart City Networks: Through the Internet of Things* (pp. 11–24). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-61313-0_2

Shang, L. W., Siang, T. G., Zakaria, M. H. Bin, & Emran, M. H. (2017). Mobile augmented reality applications for heritage preservation in UNESCO world heritage sites through adopting the UTAUT model. In *AIP Conference Proceedings* (Vol. 1830). https://doi.org/10.1063/1.4980928

Simpson, D. M. (2001). Virtual Reality and Urban Simulation in Planning: A Literature Review and Topical Bibliography. *CPL Bibliography*, *15*(3), 359–376. https://doi.org/10.1177/08854120122093078

Sisodia, A., Riser, A., Bayer, M., & McGuire, J. P. (2006). Advanced Helmet Mounted Display (AHMD) for simulator applications. In R. W. Brown, C. E. Reese, P. L. Marasco, & T. H. Harding (Eds.) (Vol. 6557, p. 62240O). International Society for Optics and Photonics. https://doi.org/10.1117/12.666350

Statt, N. (2017). Samsung partners with Google to bring ARCore platform to Galaxy devices. Retrieved January 4, 2018, from https://www.theverge.com/2017/10/18/16499080/samsung-galaxy-google-ar-core-partnership-augmented-reality

Tahyudin, I., Surya Saputra, D. I., & Haviluddin. (2016). An interactive mobile augmented reality for tourism objects at Purbalingga district. *Indonesian Journal of Electrical Engineering and Computer Science*, *1*(2), 375–380. https://doi.org/10.11591/ijeecs.v1.i2.pp375-380

Tano, S., Suzuki, K., Miki, K., Watanabe, N., Iwata, M., Hashiyama, T., … Nakayama, K. (2012). Simple augmented reality system for 3D ultrasonic image by see-through HMD and single camera and marker combination. In *Proceedings - IEEE-EMBS International Conference on Biomedical and Health Informatics: Global Grand Challenge of Health Informatics, BHI 2012* (pp. 464–467). https://doi.org/10.1109/BHI.2012.6211617

Turunen, T., Lankila, T., Pyssysalo, T., & Roning, J. (2000). Realization of mobile augmented reality based personal navigation services in 3rd generation cellular networks. *EUROCOMM 2000. Information Systems for Enhanced Public Safety and Security. IEEE/AFCEA*. https://doi.org/10.1109/EURCOM.2000.874781

Urban, E. C. (2000). The information warrior. In L. S. Hjorth, B. A. Eichler, A. S. Khan, & J. A. Morello (Eds.), *Technology and society : a bridge to the 21st century* (pp. 493–501). Upper Saddle River, NJ, USA: Prentice-Hall, Inc. Retrieved from http://dl.acm.org/citation.cfm?id=312295.314461

Vlahakis, V., Karigiannis, J., Tsotros, M., Gounaris, M., Almeida, L., Stricker, D., … Ioannidis, N. (2001). Archeoguide: First Results of an Augmented Reality, Mobile Computing System in Cultural Heritage Sites. In *Proceedings of the 2001*

Conference on Virtual Reality, Archeology, and Cultural Heritage (pp. 131–140). https://doi.org/10.1145/584993.585015

William, L. (2017). Virtual Reality vs. Augmented Reality – A Comparison. Retrieved January 5, 2018, from http://blog.mapsystemsindia.com/virtual-reality/virtual-reality-vs-augmented-reality-a-comparison/

Yovcheva, Z., Buhalis, D., & Gatzidis, C. (2013). Engineering Augmented Tourism Experiences. In *Information and Communication Technologies in Tourism 2013* (pp. 24–35). https://doi.org/10.1007/978-3-642-36309-2_3

Yu, D., Jin, J. S., Luo, S., Lai, W., & Huang, Q. (2009). A Useful Visualization Technique: A Literature Review for Augmented Reality and its Application, limitation & future direction. In *Visual Information Communication* (pp. 311–337). https://doi.org/10.1007/978-1-4419-0312-9_21

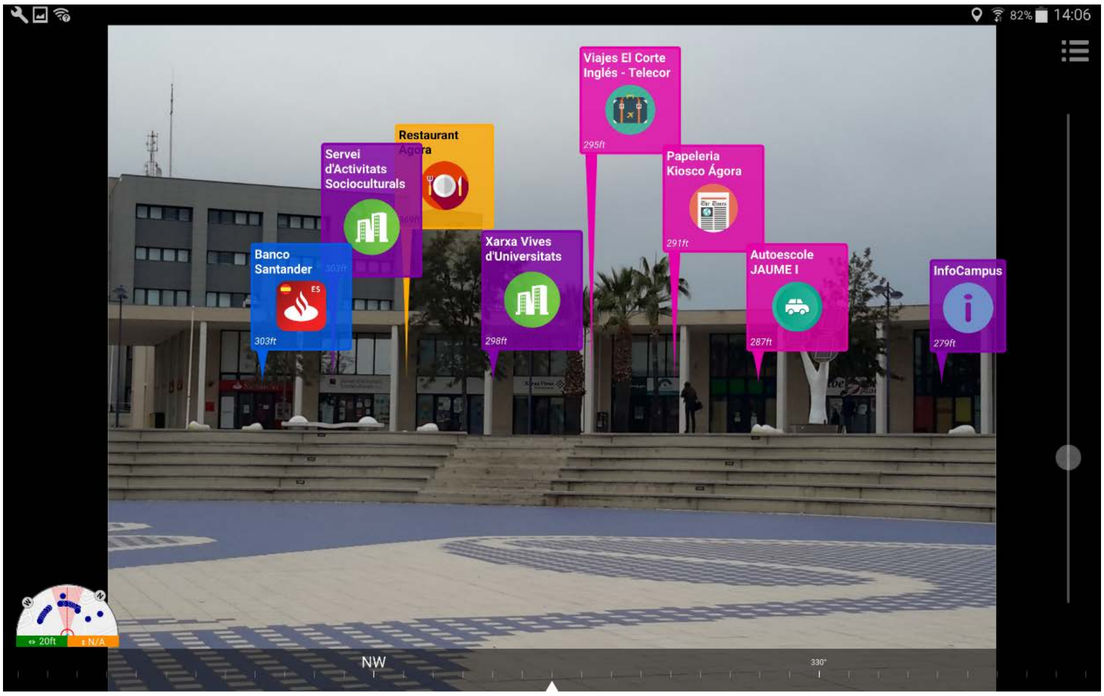
Zhao, H., Chen, H., Wang, J., & Zhang, R. (2016). Augmented Reality Game Development and Experience Based on Intelligent Mobile Phone (pp. 38–47). Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-662-50544-1_3

Zlatanova, S. (2002). *Augmented reality technology applications*. *GISt Report* (Vol. 17). Retrieved from https://repository.tudelft.nl/islandora/object/uuid:c44c5bb5-ea61-4ef0-bb39-26c91c76681b/datastream/OBJ

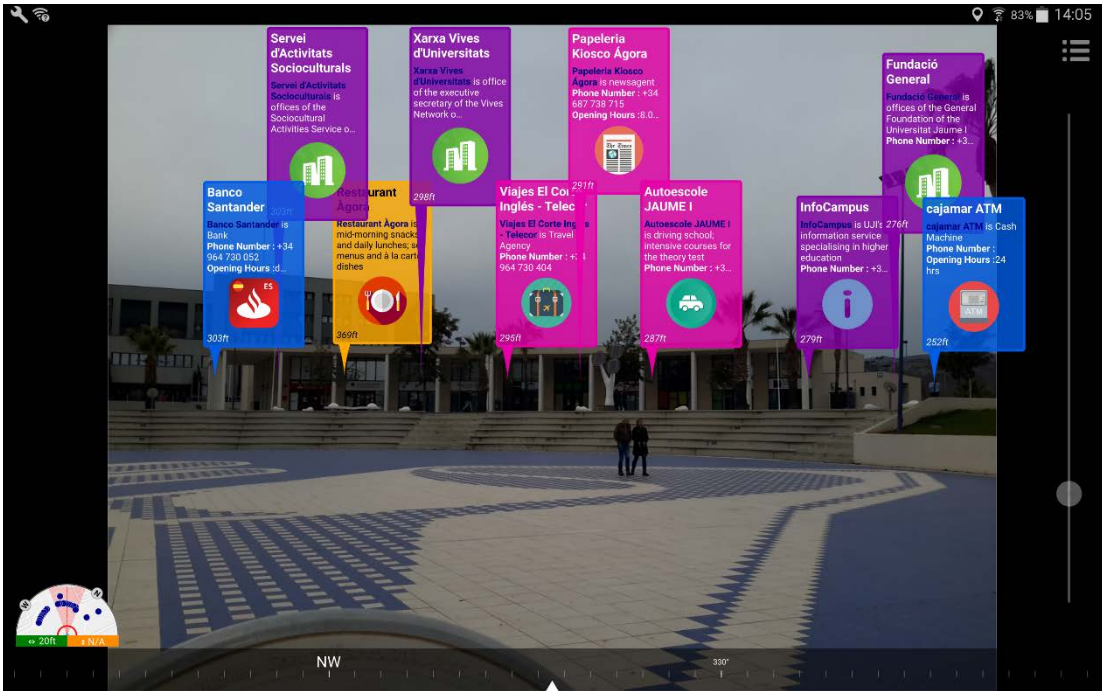
Zoellner, M., Keil, J., Drevensek, T., & Wuest, H. (2009). Cultural heritage layers: Integrating historic media in augmented reality. In *VSMM 2009 - Proceedings of the 15th International Conference on Virtual Systems and Multimedia* (pp. 193–196). https://doi.org/10.1109/VSMM.2009.35

APPENDICES

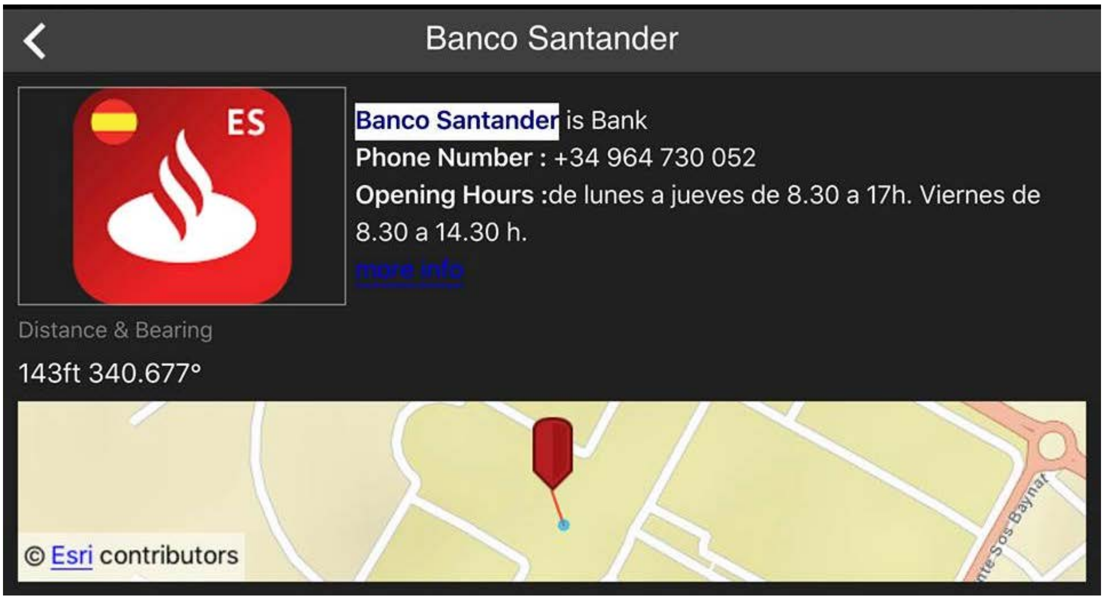
1. Opening Screen of the ARUJI app



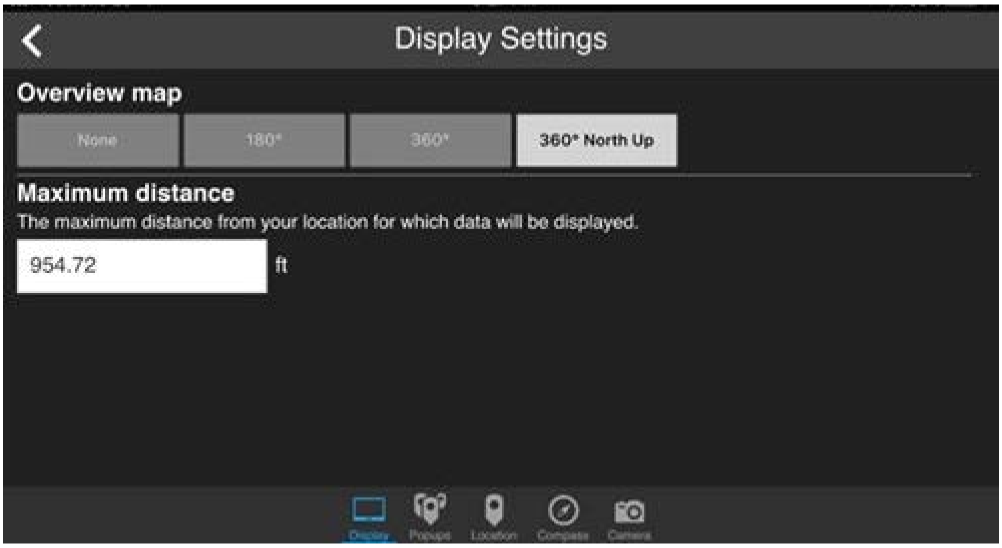
2. Display of POIs with only icons and designation.



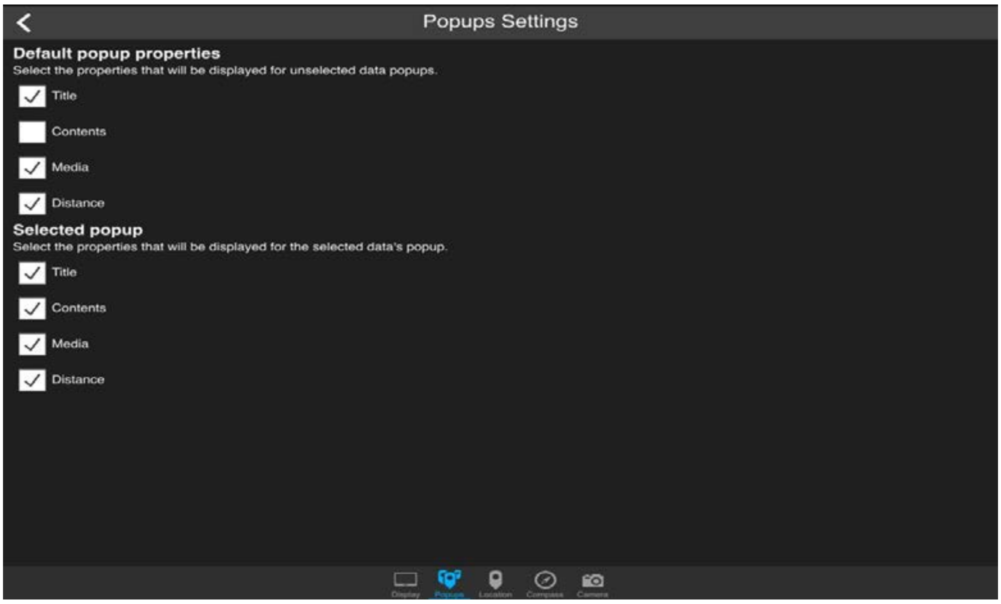
3. Display of POIs with icons and designation and information.



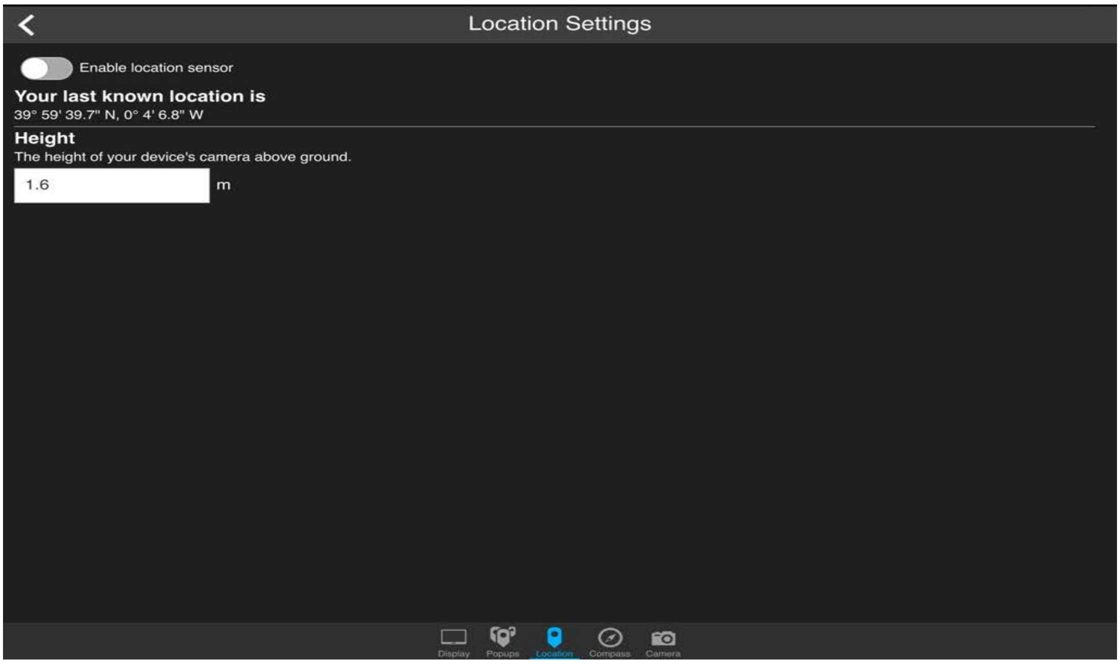
4. Display of information after clicking the popup.



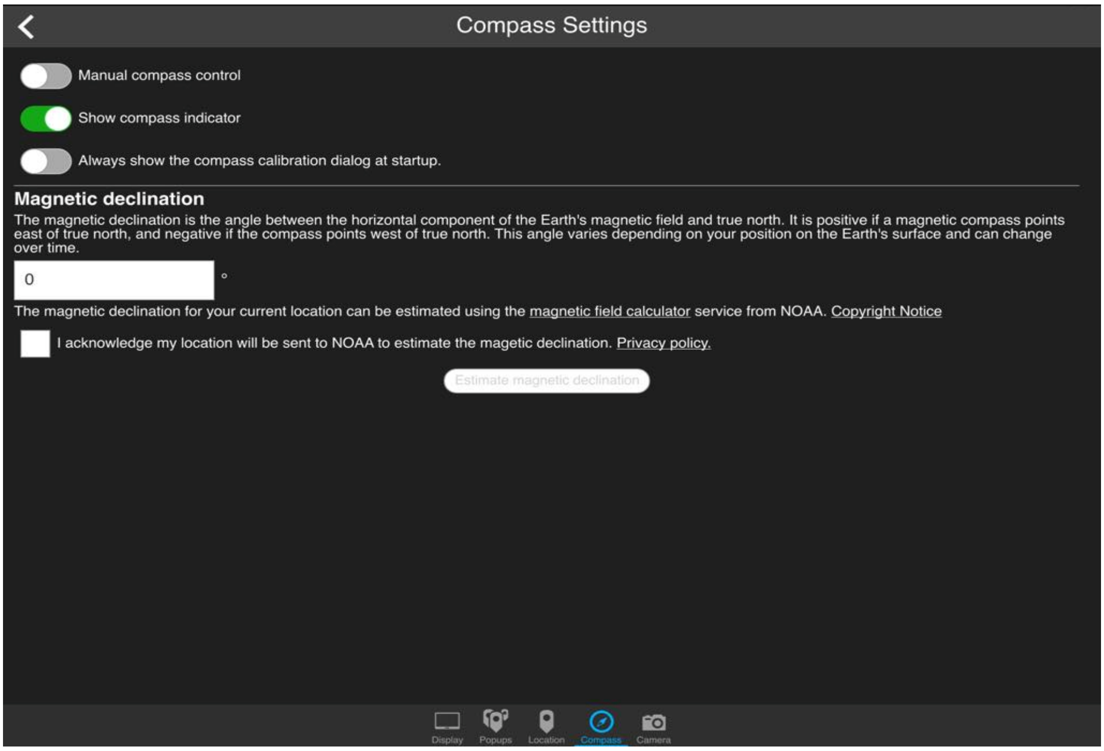
5. Display Settings for setting the minimum distance of data to be displayed.



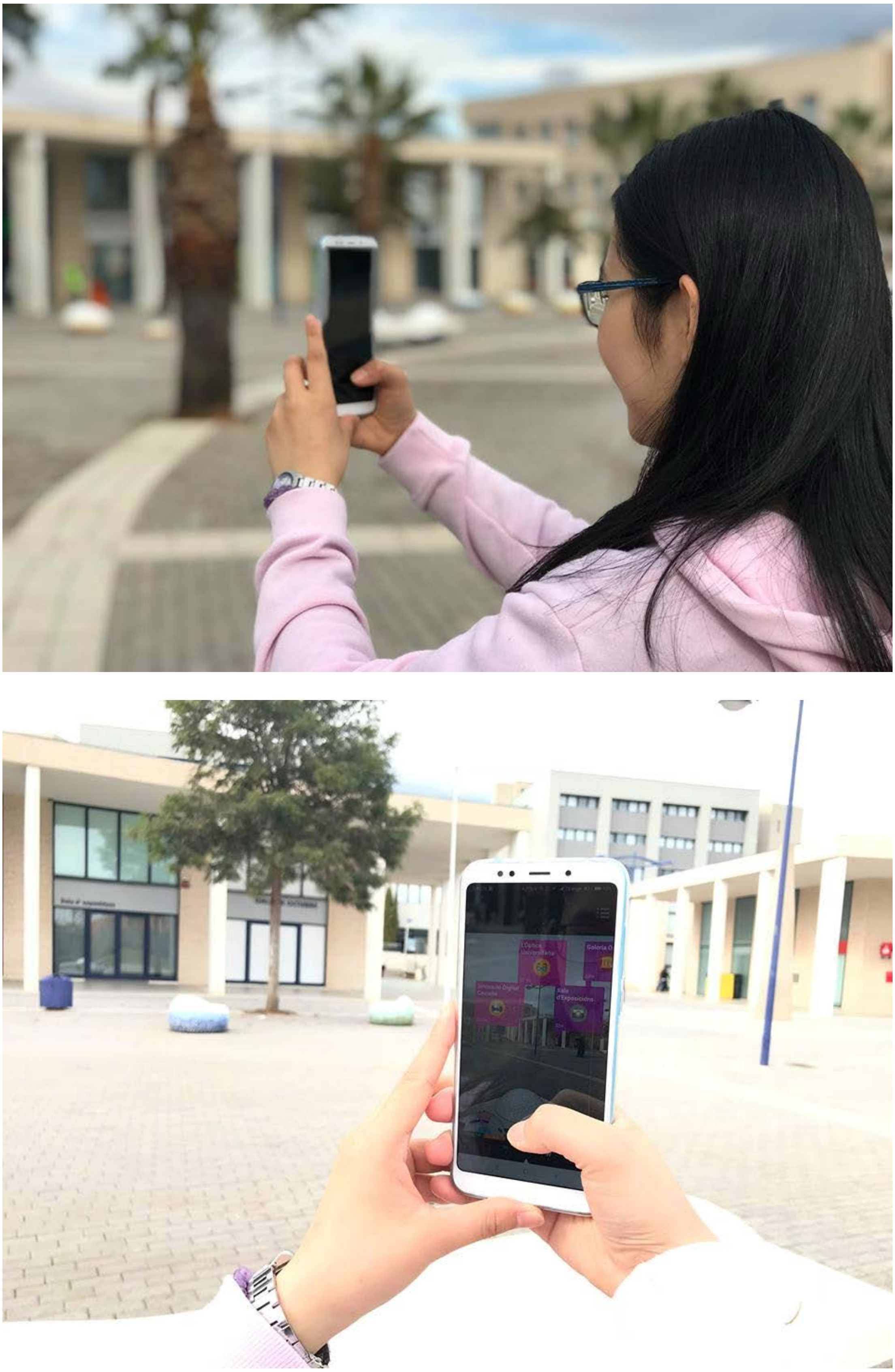
6. Popups Settings



7. Location Settings



8. Compass Settings



9. Participant using ARUJI app.

10. Questionnaires

General Statistics

Questionnaire related to personal information

* Required

1. **Gender** *

   Mark only one oval.

   - Male
   - Female

2. **Age** *

   Mark only one oval.

   - < 18
   - 19 - 25
   - 26 - 35
   - 36 -50
   - 50 +

3. **Level of your Studies** *

   Mark only one oval.

   - No studies
   - Primary studies
   - Secondary studies
   - High school graduate
   - Bachelor's degree
   - Master's degree
   - Doctorate degree

4. **Country**

   ____

5. **Do you have interest in technology?**

   Mark only one oval.

	1	2	3	4	5	
None	◯	◯	◯	◯	◯	Very High

Augmented Reality

Questions in this section are related to basic Knowledge into Augmented Reality (AR). One of the best examples of AR is Pokemon GO, 3D masks and special effects in Facebook, Instagram, Snap chat etc.

6. **Have you heard about Augmented Reality? ***

Mark only one oval.

- ◯ Yes
- ◯ No

7. **Do you own a smart phone or tablet? ***

Mark only one oval.

- ◯ Yes
- ◯ No

8. **Have you used (or download) any Augmented reality application on a smart phone or a tablet? ***

Mark only one oval.

- ◯ Yes
- ◯ No

9. **Below are some applications of Augmented Reality? Which ones have you used? (Select Multiple if necessary) ***

Check all that apply.

- ☐ Pokemon GO
- ☐ Ikea Place
- ☐ Layar
- ☐ AR MeaseureKit
- ☐ Google Translate (translating with camera)
- ☐ Google Skymap
- ☐ Facebook, Instagram, Snapchat, AR effects
- ☐ Yelp
- ☐ Wikitude
- ☐ None
- ☐ Other: ____________________

10. **Why do you use it (them)?**
Check all that apply.

- [ ] Curiousness
- [ ] Trending technology
- [ ] Informative
- [ ] Entertainment
- [ ] Suggested by friends
- [ ] suggested by App store or Google store
- [ ] Other: ______________________

11. **How was your experience using these Augmented Reality apps?**
Mark only one oval.

	1	2	3	4	5	
Bad	⬭	⬭	⬭	⬭	⬭	Best

12. **How often do you use AR applications?**
Mark only one oval.

	1	2	3	
Rarely	⬭	⬭	⬭	Often

AUGEO

It is an AR mobile app to visualize GIS data in an augmented reality environment.

13. **Have you ever used AR app for searching information around you? ***

Mark only one oval.

- ◯ Yes
- ◯ No

14. **Which app do you use for searching places and information around you? ***

Check all that apply.

- ☐ Google Maps
- ☐ Maps.Me
- ☐ Apple's Maps
- ☐ Here Maps
- ☐ Other: ______________________

15. **Have you ever been lost or misguided using the above apps? ***

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Maybe

16. **Did you enjoy your experience with the AuGeo app?** *

Mark only one oval.

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Very Much

17. **How effective did you find ARUJI over other 2D Map view apps?** *

Mark only one oval.

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Very Much

18. **Which is more effective?** *

Mark only one oval.

◯ ARUJI

◯ Other Map apps

19. **Were you successful using the Augeo app?** *

Mark only one oval.

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Very Much

20. **Were you able to control the system?** *

Mark only one oval.

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Very much

21. **Is the information provided by the app clear?** *

Mark only one oval.

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Very Much

22. **Did you feel discomfort during your experience with the AuGeo app?** *

Mark only one oval.

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Very much

23. **Do you think that this app (AuGeo) is helpful in what you are looking for?** *

Mark only one oval.

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Very Much

24. **Is it more comfortable to use than google maps or any other mapping apps of your choice?** *

Mark only one oval.

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Very Much

25. **Did you know other AR apps similar to Augeo?** *

Mark only one oval.

◯ Yes
◯ No

26. **Had you known such AR apps existed, would you use such app?** *

Mark only one oval.

◯ Yes
◯ No
◯ Maybe

27. **If no why?**

____

28. **Will you prefer using this app or continue using the previous app?** *

Mark only one oval.

◯ Yes
◯ No. Continue using previous app
◯ Maybe

29. **Are you satisfied with the application Augeo?** *

Mark only one oval.

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Very Much

30. **11. What improvements or suggestions are needed from your point of view?**

11. Time taken to complete the task by the participants in completing the task 1 and task 2 in secs.

	Task 1		Task 2	
Participants	**Map View**	**AR View**	**Map View**	**AR View**
1	9.43	6.23	26.37	18.93
2	7.36	6.39	13.36	10.74
3	7.09	6.55	24.3	13.38
4	9.49	5.56	10.2	10.7
5	8.76	6.86	15.5	10.62
6	10.75	6.79	13.65	14.85
7	8.8	7.93	13.5	10.89
8	10.4	7.6	11.42	9.73
9	10.1	6.92	14	12.38
10	8.99	7.27	12.62	11.2
11	8.73	6.09	13.43	11.76
12	9.66	7.21	13.82	15.25
13	8.17	6.59	15.63	11.23
14	8.73	7.25	11.89	13.11
15	9.27	5.69	12.83	10.6
16	9.17	6.04	15.73	10.39
17	9.73	7.29	11.32	11.12
18	9.83	6.69	12.69	11.87
19	8.93	7.65	11.4	12.39
20	8.63	6.38	10.63	9.89
Sum	182.02	134.98	284.29	241.03
Average	9.101	6.749	14.2145	12.0515