EARL: Earlham Augmented ReaLity Campus Tour Application

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ABSTRACT

Getting lost when visiting an unfamiliar place is a nerve-wrecking experience for many people. In fact, the constant fear of being lost hinders one from being able to explore and learn about the new place with a free mind. Even with the assistance from a guide or some local people, the information an individual can obtain about his or her surroundings is limited and depends hugely on the availability of such people. By using a technology called Augmented Reality, this application will serve as a virtual tour guide for all visitors of Earlham College. Visitors will be able to learn more about Earlham by interacting with the augmented virutal information and explore the campus freely without any other aid. With EARL, the application for better campus tours, all information you need is at your fingertips.

Keywords

Augmented Reality; Mobile App; Campus tour; Ubiquitous learning; Navigation

1. INTRODUCTION

Imagine yourself being on a university campus that you have never been before. With the assistance of a student or a person who has been there for a while, knowing your location would be difficult. You will need to have a traditional map and approach some random strangers to know where a certain building or what the purpose of that building is. The way one will get information about the university or college highly depends on the availability of such people and tools. When there are not a lot of resources to rely on, exploring a campus becomes a less fun and more tedious experience. The bigger the campus is, the more time-consuming and ineffient a tour around the campus will be. Do you not wish to have a guide in your pocke? This paper will introduce an mobile application that harnesses the power of Augmented Reality to tackle this problem.

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Augmented Reality is one of the technologies that will be able to provide a ubiquitous learning environment in the near future. Although Augmented Reality as a concept has existed since the 1960s, it is only in the recent decades that the technological advances make it a possible research[8]. Yovcheva and et al. pointed out that the strength of mobile based Augmented Reality application is that they can be used to access personalized and updated information at any time and place and, by using them, the users will be able to view information about an object of interest in their surroundings[12].

Augmented Reality has already been used in a number of different fields such as medical, military, entertainment and education and continues to be integrated into many new areas in a steady pace[4][5][10]. The reason why Augmented Reality is proven useful in such areas is that it possesses the ability to help the users visualize and assess the information and features that is not possible to be included or created in the real world. The users can interact with the virtual information on their devices of choice and retrieve more information than what a label or similar descriptive materials can offer.

Over last few years, there have been several attempts in creating navigation applications that use Augmented Reality[3]. However, most of these applications are navigation systems for drivers. A few of them are applications that show points of interest in the surrounding area of the user. They do not have information more than what a place is (for example: a restaurant). There was an application called "TigerEye" that is designed for navigation on the campus of Clemson University.[11]. However, navigation is the only function the application can deliver.

The application for this project, EARL, is unique and different from the AR applications on the market because it is designed solely for better campus tour experiences. By combining the elements of navigation and virtual information overlays, the application will bring a new level of campus tour experience to the users. Moreover, the idea is scalable. It is not limited to just Earlham College or just a college campus. The concept can be applied to unfamiliar places like hospitals, museums, carnivals and festivals or large scaled areas like a town. Fun activities like treasure-hunting and haunted houses can use this to create more interactive and engaging challenges.

This paper introduces a mobile Augmented Reality application that is designed to provide essential information to the users to freely explore the campus of Earlham College.

The users will be able to use nearby target images and markers to access immediate detailed information and use their current location and GPS to access information of buildings from afar.

The rest of the paper is organized as follows. Section II introduces the term Augmented Reality and its current state of the art. Section III presents the application EARL and its hardware and software components. Conducted experiments and challenges of mobile AR applications are discussed in Section IV. Section V includes the conclusion and future work.

2. AUGMENTED REALITY

2.1 Definition

There is no solid definition for the term Augmented Reality. Augmented Reality has been evolving for a certain period of time but the term is still loose and lacks proper standardization. According to Azuma, Augmented Reality is a variation of Virtual Reality[5]. While, the real world of the user is replaced with a virtual environment in which the user is immersed in Virtual Reality, Augmented Reality allows the users to see the real world with virtual objects superimposed upon the real world environment without replacing the surrounding environment. It makes the users feel that the virtual and real objects co-exist in the same space. Therefore the users will be able to get additional virtual information while they can still see, hear, touch and feel in the real world. WIthin an AR-enhanced context, the infomation becomes interactive and easily manipulated in a digital manner[8]. Azuma defined Augmented Reality as a system that has the following three characteristics:

- Combines real and virtual
- Is interactive in real time
- Is registered in three dimensions

[4][5].

These three characteristics widen the realm of Augmented Reality and I will use this definition as the principles in designing AR applications and as a gauge for this survey paper.

2.2 Current State of The Art & Related Work

The beginnings of AR go back to Sutherland's work in the 1960s, in which he used a seethrough head-mounted device to present 3D graphics in an AR prototype. However, only over the past decade has there been enough work to refer to AR as a research field[4]. The field starts to get its attention and is proven to be useful because Augmented Reality enhances a user's perception of and interaction with the real world[5]. As mentioned, AR applications superimpose 3D and/or 2D graphics on top of the real world view. Therefore, the available information can be continously updated through new objects. In turn, there objects and 2D graphics are inserted and handled by the AR applications with the help of GPS data, or AR fiducial markers, which can be easily recognized by mobile devices and computers[8].

Along with an increase in power and capability, and a decrease in cost and size of computing devices, the ability to artificially create simulations in real time offers opportunities for Augmented Reality to reach its full potential[6]. One of the major requirements for the development of Augmented Reality technologies is the development of the required components[7]. The technological demands for Augmented Reality are much higher than for Virtual Reality, and that is one of the reasons why the field of AR took longer to mature than that of VR. However, the key components to build an AR system have remained the same since Ivan Sutherland's pioneering work of the 1960s. Displays, trackers, and graphics computers and software are still essential in creating Augmented Reality experiences[10]. Yuen and et al. have researched that Augmented Reality research tends to purse either (a) the development of new devices and technologies for the essential components of the tracking, display, and input of real world and virtual data, or (b) the development of applications utilizing such existing technologies[13]. According to Zhou and et al., AR research has focused primarily focused on five core areas essential to deliver AR applications: (a) techniques for tracking (20.1%), (b) techniques for interaction (14.7%), (c) calibration and registration issues (14.1%), (d) developing AR applications (14.4%), and (e) display techniques (11.8%)[14]. Although the field of Augmented Reality is still immature compared to Virtual Reality, recent advanced researches in AR and rapid growth of the capabilities of mobile devices becomes AR technology relevant in many areas such as medicine, education, military and entertainment where rapid information transfer is critical.

2.3 Challenges, Limitations and Proposed Solutions in the Field of Augmented Reality

At the moment, the researchers agree that there are a number of challenges related with mobile technology and using mobile technology to create Augmented Reality applications. The challenges and constraints can be categorized into three categories:

1. Technical limitations
2. Environmental limitations
3. Social limitations

Realizing the limitations and challenges before the actual development allows me to consider these factors in designing the application and know what to expect as a result. Understanding the difficulties beforehand makes my expectations for EARL more realistic and organized.

2.3.1 Technical Limitations

The main technical limitation is the limited resources of mobile devices. Mobile devices have limited computational capability, limited memory, limited input/output options as well as limited graphical power. The capability of the AR application is highly dependent on the capability of the device it is implemented on. According to Craig, Memory is a primary limitation on the amount of content that can be resident on a mobile device at any given moment[6]. He proposed two primary ways to overcome the limited memory available on a device. The first is to use clever schemes to limit the amount of memory that the content occupies. One way to do this is to limit the number of polygons and size of textures that are associated with visual objects and to limit the applications in the number of objects that are expected and/or required. The other way to overcome the issue of limited memory is to create a scheme by which content is loaded onto the device when needed and off-loaded when not needed.

Real time 3D tracking is also an issue that limits the full potential of Augmented Reality. The complexity of the background scene and the motion of target objects, including the degree of freedom of individual objects and their poses[14]. Zhou and et al. proposed to use marker-based tracking to enhance robustness and reduce computational requirements. However, the markers need maintenance and suffer from limited ranges. The method is not scalable when the application is used in an outdoor environment. Tracking in unprepared environment also remains an unsolved problem[4]. This is related with both technical limitations of devices and the environmental factors.

Another obstacle is the lack of interoperability across mobile platforms[8]. Even though there are many frameworks and toolkits for developing mobile AR applications, the applications cannot be used across all operating systems. Augmented Reality devices may also need data network connection to download relevant contents. Not all places are fully equipped with Wi-Fi networks and data roaming charges will make the users hesitant to use the applications. This constraint can hinder the application to reach its full potential[6][8].

2.3.2 *Environmentall Limitations*

Apart from the constraints of the devices themselves, there are environmental factors that will hinder the development of mobile AR applications. The developers have no control over the environmental conditions such as lighting, noise, weather and other factors. In all cases of augmented reality applications and devices that use computer vision for tracking, it is essential that there is enough ambient light of the appropriate wavelength in the environment for the vision system to "see" the world[6]. Moreover, there can be locations that might restrict the types of devices that you are allowed to carry/use. Virtually all devices are restricted on commercial air flights during takeoff and landing, and only certain devices are allowed while the plane is at altitude. Facilities where electromagnetic interference is hazardous may not allow the use of mobile devices. Mobile devices are also not suitable to use in areas with extreme environmental measures.

2.3.3 *Social Limitations*

The challenge with society is whether the society will embrace the new technology and accept it. If it is too hard for the user to understand the technology, then the user will not welcome that technology. Mobile Augmented reality presents the challenge that there could potentially be content anywhere[6]. The users will have to know which targets would produce augmented reality contents in order to trigger those targets. Sometimes, they might even to need to use the application from a certain pose or point to activate those AR contents. If there are multiple AR applications in their mobile devices, finding right targets for the right application would be difficult. Azuma pointed out that perception is what counts, even if the technological reality is different[5]. In his example, if people perceives lasers to be a health risk, they may refuse to use a system that uses lasers in the display or trackers, even if they are perfectly safe. Moreover, security and privacy concerns cannot be overlooked. It is easy to imagine that spam would overwhelm the augmented world with unwanted advertising or information[6]. Malicious applications might mislead the users by giving wrong informations or steal valuable personal information by scanning. Roesner and et al. argued that, while the field of Augmented Reality is young and malleable, we should consider security and privacy issues posed by the AR systems and explore new technologies to create novel privacy and security enhancing applications[9].

3. EARL: A CAMPUS TOUR APPLICATION FOR EARLHAM COLLEGE

EARL is designed with the purpose of serving as a virtual guide for your visit at Earlham College. By taking advantage of Augmented Reality's ability to augment virtual objects, the application will provide crucial information imposed on the real world environment that can keep the users engaged while making the tour more enjoyable and less stressful.There are two key components in creating EARL: the hardware and the software. The details of the components will be covered in the following subsections.

3.1 Hardware

EARL will be an Android application. However, as the progress goes on, iOS version of EARL will be developed in the near future. To develop a Augmented Reality mobile application, we need a specific hardware. There are certain core requirements that the chosen device for implementing augmented reality must meet. First of all, the device must be an android device. It has to support a fairly recent version of Android OS (Android 4.0+ is recommended for AR development). The device must also possess GPS for tracking the user's current position within the world. Having accurate readings of a user's location is essential in creating precise Point of Interest virtual markers near the user and calculating a route and its distance from the current location to the desired destination. The device requires a rear-facing camera so that the user can point at markers or target images while still looking at the screen for virtual information. Moreover the camera is vital for the device to determine the location of the object or building on which it should augment virtual overlays. In other word, camera is the main method for the software to accept inputs and impose its artificial information overlays. Furthermore, the reason why the users can observe and interact the virtual information as if it were in the real world is that the camera tracks the background while the software renders the overlays.

The chosen device should also have an accelerometer to detect movements. The imposed materials will be augmented relative to how the user moves his camera around or how fast the user is moving. The ability to be able to connect to the internet will be very useful in the process of further development and improvement. Moreover, cloud-based database can be an option if the data becomes too large to be embedded in the device. For most mobile devices, the battery life and CPU power are limited. To render and augment 3D objects smoothly, the device must have a capable CPU (armv7a and NEON support). Rendering 3D models also requires a lot of power for the graphics and drains battery rapidly in the process. Having a good battery would be necessary to run the application while exploring the campus.

3.2 Software

In this section, the details about SDKs and libraries involved in the development, framework of the software and the implementation of the application will be discussed.

3.2.1 Software Development Kits(SDK), and frameworks & Libraries

As EARL is an Android application, it is written using Android SDK. The language for implementing Android applications is Java and the Android SDK comes with a number of libraries necessary to design and create Android applications. In addition to Android SDK, the development of EARL involves Apache Cordova[1] application development framework. Since it supports both Android and iOS platforms, it is ideal for prototyping applications.

There are several SDKs available to create an Augmented Reality mobile applications. In this project, Wikitude SDK[2] is chosen to implement the AR feature of EARL as Wikitude offers a variety of powerful APIs to add Augmented Reality context to the mobile application. Moreover, it conveniently has a specific SDK designed for Cordova.

3.2.2 Framework

The framework of EARL is shown in Figure 1. The software contains two main parts: recognition combined with tracking and rendering. The inputs of the application will be the visual cues such as certain objects, tags and fiducial markers and geo-based cues like GPS locations. Depending on the cues, how the application behaves will defer. For the case of visual targets, the application will scan the camera's view and search for a marker or an object when the user opens the application and points its camera to something. While doing so, it will constantly check with the database to see if there is a match. When the match is found, the application will render the respective virtual drawables of the target on top of the target. The overlays can be in the form of images, videos, 3D objects and buttons. For the feature that uses GPS locations, the application will start to determine the user's current location using the device's GPS service when the application activity is initiated. While doing so, the application will also access the database for the locations of the points of interest and create ARmarkers for them. In the next step, the ARchitectworld will handle the process of rendering the POI markers on the screen. If the user is nearby the markers in the real world, the user will be able to see the virtual markers superposed on top of the interesting buildings and structures in his or her surroundings.

3.2.3 Implementation

With the help of Cordova, the implementation of the application is written in JavaScript and then later converted to Native Android application. Different activities of the application are created by making several web pages and converting them into more native versions of them. EARL has two core features: Augmented Reality information and Navigation.

In Augmented Reality feature, there are two ways to provide relevant information for the users. The first one is using target images and markers. A number of photos of objects - preferably flat - and markers are collected beforehand. By using a targetmanager provided by Wikitude, the collected images of objects and markers are converted into images that can be recognized by the Wikitude SDK. The tool generates a digital footprint of the images and stores that in a target collection file (.wtc file). The wtc file has to be included in the asset folder of the project to be recognized by the SDK. In in the future when there are a lot of target images to be collected, cloud storage can be used to store all the images without embedding in the application.

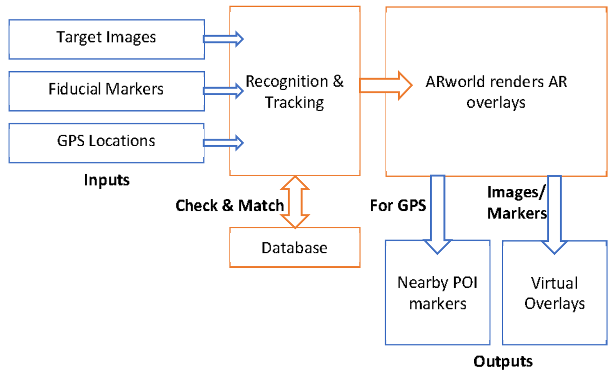

Figure 1: Framework of EARL

The implementation layout of the feature is similar to that of a web page. It has folders for assets, css, js and index.html. The JavaScript files in the js folder are the backbone of the logic of the feature. In js file, a AR variable called World is created at the beginning. When the activity of this feature is initiated, the ARWorld is loaded and an AR.ClientTracker is created in order to start the recognition and tracking engine. The ClientTracker is a tracker for Augmented Reality and uses the wtc file for its reference. It is initialized with a URL to the wtc file mentioned above. The next part is creating virtual overlays for displaying the information. The overlay displays related to each image in the wtc file are stored in the asset folder. When the recognition engine starts, each display is passed into an AR variable called ImageDrawable which is a virtual component that can be connected to a target image or marker. Then the tracker, the name of the image target defined in the target collection and the drawable are combined to create an an AR variable called Trackable2DObject which would augment the overlay on top of the recognized image.

The second method is using GPS locations to display augmented objects. In this method, all information about points of interest such as latitudes, longitudes, altitude and their descriptions are stored in a separate Json file. These data can also be stored using a web page hosted on the internet. Similar to the beginning of Augmented Reality feature, a AR variable called World is created in the beginning of this code. Then an array for markers is created and all the information of the points of interest is pushed into this array. The status of loading POIs from the database can be checked by clicking on the small "i" button at the bottom. The application creates POI markers on the screen depending on their coordinates when all the markers are full loaded. When a POI marker is tapped, a window will slide out to show the details about that specific building or place. A function called DistanceToUser is used to calculate the distance between that marker and the user.

4. EXPERIMENTS

Moreover, experiments are carried out in order to understand the challenges in real life environment and to verify that the application is working as it is expected.

4.1 Experiment Environment

The experiment is conducted on a Nexus 5 mobile phone and the target images are taken with the camera of this phone to ensure that there will not be any differences of resolution. Also the experiments are conducted at both day and light to observe how far the recognition ability of the application can go. The experiments are performed in the real environment so that I can check the positions of the POI markers on the screen are relative to the positioning of the buildings.

4.2 Result

4.2.1 Image Recognition

The recognition feature of Wikitude SDK is designed mainly to use on 2D flat images. According to the Wikitude website, the developers are encouraged to use images that have rich contrast and many corner like structures. Therefore the application is first tested with the sample images given by the wikitude SDK. Then the images are substituted with images taken on the campus of Earlham College. These include banners, signs and buildings. The image recognition ability of the application works very well with the test images, recognizing every photo without a problem.

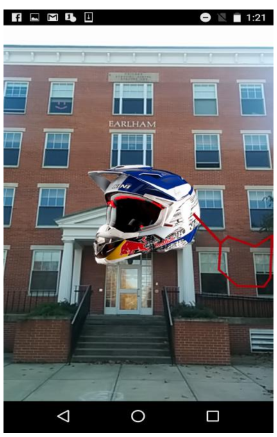

Figure 2: Testing with Earlham Hall

In order to test the true capability of the application, the experiment is extended to testing with real life buildings and structures at Earlham. During the experiments, it is remarkable that the Wikitude SDK recognizes the real life objects very well as it is proved in Figure 2 & 3. The only problem is that the user will have to hold the phone and point the camera at a similar angle I used to take the photos of the objects for the application to be able to recognize the object.

4.2.2 Daytime & Night-time

The application is designed to be usable and accessible at all times anywhere. Therefore the application must be tested to observe its performances under certain environmental effects. Lighting plays a huge role on the scale of visibility and

Figure 3: Testing with Earlham banner

I wanted to make sure that the application will recognize images under low light situations as well. As it is demonstrated in Figure 4(a) & (b), the application can recognizes the sign during both daytime and night-time. However, buildings or structures that become different at night will be easily recognized by the application at night. For example, Earlham Hall will look different when residents turn on the lights at night.

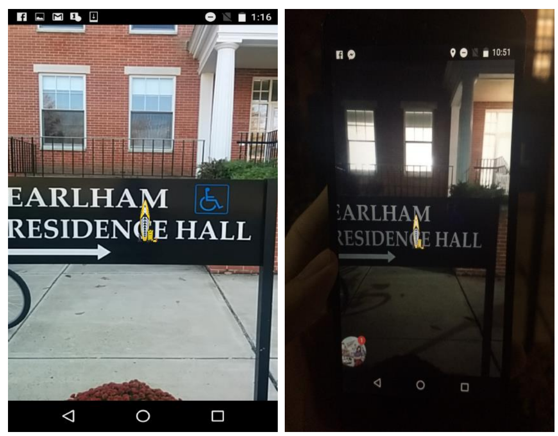

Figure 4: Testing Image Recognition (a) During Daytime and (b) During Night-time

4.2.3 POI markers

POI markers play an integral part of the application. In POI mode of EARL, the user will be able to see the markers hovering on the buildings on their screen. Therefore, the positions of the markers must be relative to the actual positioning of the building on the campus. This experiment is tested by going to different places on the campus and testing the application. In the experiments, the application can show the markers at their relative positions anytime anywhere. In Figure 5 & 6, the markers can be seen at their respective buildings. Moreover the positions of the markers are relatively correct in the mini map as well.

When the markers are tapped, they are supposed to show the description of the place and the distance from the user to that place. Figure 7 demonstrates that the application

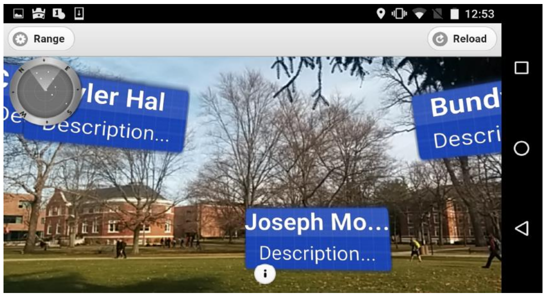

Figure 5: POI Markers at Relevant Positions

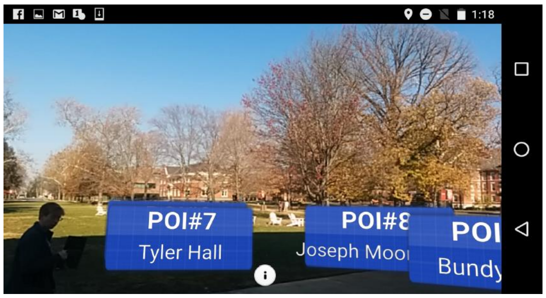

Figure 6: POI Markers at Relevant Positions

will show a slider window with information relevant to a place when the marker of that place is tapped. We can see that the distance is calculated based on the user's current position.

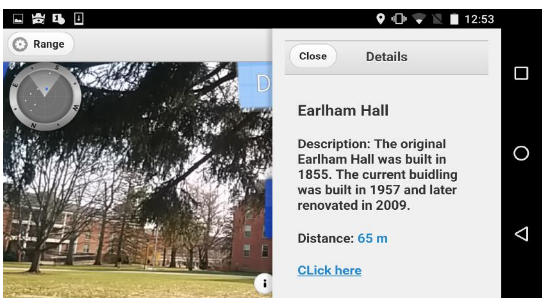

Figure 7: Testing Description and Distance from user

5. CONCLUSIONS & FUTURE WORK

In this paper, we can see the beginning of an application that can inspire a variety of different uses of Augmented Reality. EARL is simple, user-friendly and designed to provides valuable information to the user within a few taps on the screen. Since the field of Augmented Reality is not as well developed as Virtual Reality is, we can see that there are many challenges waiting for us. AR has come a long way but there is still distance to go before the technology is widely accepted and utilized as a familiar user interface. Future research within this field of mobile AR should be focused on creating better solutions for markerless object recognition such as natural feature detection, improving computer vision algorithms to analyze and determine the object's representation, deciding whether content should be stored on the device or remote server and protecting the privacy and security of the users ethically.

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