TouristicAR: A Smart Glass Augmented Reality Application for UNESCO World Heritage Sites in Malaysia

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***Abstract*—Modern day technologies including wearable devices such as smart glasses have changed the way people interact with their surroundings. Such developments have resulted in the increased popularity of Augmented Reality (AR) applications to project context-aware information on objects or users' immediate surroundings. In order to enhance the overall tourism experience, a number of recent works have highlighted the opportunities for using outdoor AR or navigation-based AR systems. Due to the development of context-aware AR, tourists using such technology can acquire valuable knowledge and experience. Recent context-aware AR research lack empirical studies and works that integrate dimensions which are specific to cultural heritage tourism and smart glass specific context. This work presents the mapping of requirements identified during the affinity mapping and focuses group experiments into a smart glass-based AR application called "TouristicAR" to identifying the factors of user acceptance and specific tourist requirements. This works highlights the technical requirement, design conceptualisation, smart glass User Interface (UI) design and smart glass application development using a Rapid Application Development (RAD) methodology. The smart glass AR application is developed in the context of cultural heritage tourism and provides context-aware and visually appealing tourism contents to the visitors at the UNESCO World Heritage sites in Malaysia.**

***Index Terms*—Augmented Reality; Cultural Heritage Tourism; Rapid Application Development; Smart Glasses; User Acceptance.**

I. INTRODUCTION

The rise of new communication and information technologies has tremendously influenced how tourists interact with tourist attractions. Modern day technologies including wearable devices such as smart glasses have changed the way people interact with their surroundings. Such developments have resulted in the increased popularity of Augmented Reality (AR) applications to project context-aware information on objects or users' immediate surrounding [1-4]. In order to enhance the overall tourism experience, a number of recent works have highlighted the opportunities for using outdoor AR or navigation based AR systems [5-7].

Due to the development of context-aware AR, tourists using such technology can acquire valuable knowledge and experience without the need of any tourist guide.

A variety of context-aware AR usage examples can be seen in the domain of tourism in general [8-13]. Without examining the user acceptance and behaviour, it becomes a difficult task to measure the potential of emerging technologies. Although recent works shed some light on the acceptance of smartphone-based AR acceptance in tourism settings, however, the investigation of potential factors affecting the user acceptance in the context of smart glasses-based AR is limited. While [14] have researched tourist acceptance on smartphone AR based on Technology Acceptance Model (TAM). They found factors such as information quality to have a major impact on user acceptance.

To overcome the inconsistencies posed by TAM, [7], [15] also researched tourist acceptance on smartphone AR based on an integrated model Technology Readiness Acceptance Model (TRAM) emphasising the importance of visual appeal and technology readiness but ignored the important information quality factor. These authors argued that the investigation of the tourist acceptance based on smart glass AR is very limited and requires further examination regards to identifying the factors of acceptance and specific tourist requirements.

Recent studies on smart glass acceptance in domains other than tourism clearly highlight the importance of both; visual appeal/aesthetics and information quality along with other factors to enhance user acceptance. Therefore, to address this gap [1], [2] presented a smart glass-based AR acceptance model which identifies information quality, technology readiness, visual appeal, and facilitate conditions as external variables and key factors influencing visitors' beliefs, attitudes, and usage intention.

This work presents the development and implementation of the model presented by [2] and the requirements identified during the affinity mapping and focuses group experiments into a smart glass-based AR application called "TouristicAR". Hence, this works highlights the technical requirement, design conceptualisation, smart glass User Interface (UI) design and smart glass application development using the Rapid Application Development (RAD) methodology. The smart glass AR application is developed in the context of cultural heritage tourism and provides context-aware and visually appealing tourism content to the visitors at UNESCO World Heritage sites in Malaysia.

II. DEVELOPMENT METHODOLOGY

The methodology for the development and implementation of “TouristicAR” consists of two main elements, feature mapping where the design is conceptualised in the form a visually appealing UI and later implemented in a working smart glass proof-of-concept application. The developed model is revised before the feature mapping and application development process.

A. Research Model Revision

The identification of user acceptance factors and dimensions for smart glasses AR acceptance is crucial as research in this area is scarce. To the best of our knowledge, this is the first work carried out to identify the dimensions for the acceptance of smart glasses-based AR at UNESCO World Heritage sites. The work by [2] identified these dimensions by conducting a step by step thematic analysis of potential external dimensions within the context of AR acceptance suggested by [16]. The smart glass AR acceptance model for cultural heritage tourism in [2] is presented in Figure 1.

To develop the model, affinity mapping was conducted with 28 participants to identify main themes followed by in-depth analysis of five focus groups with 30 participants which helps to establish the sub-themes. According to the finding of the initial research, four main dimensions; Visual Appeal, Information Quality, Technology Readiness, and Facilitating Conditions affect the perceptions and the behavioural intentions of the tourists. In addition, similar to previous TAM [14] and TRAM [7], [17-18] studies, the findings emphasise that Perceived Usefulness (PU) and AR attitude are positively impacted by Perceived Ease of Use (PEoU). Also, it is suggested that PU has a positive effect towards AR attitude, which in turn affects the intention to use and consequently impact the actual user behaviour and intention to visit a tourist destination.

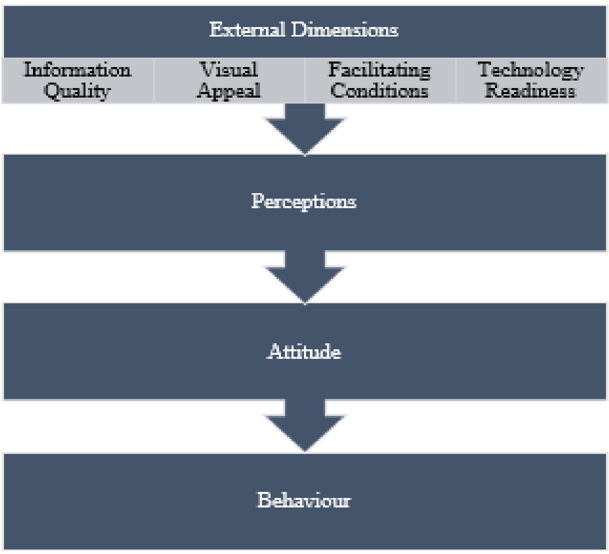

Figure 1: Smart Glass Acceptance Model

B. Feature Mapping

Feature and function mapping are one of the first processes required for the implementation of the acceptance model in the form of a smart glass AR application. It consists of three main steps; requirement analysis, design conceptualisation and UI design as shown in Figure 2. [19]. Requirements analysis is perhaps one of the most important phases of the design process. In this phase, it is necessary to translate the broad goals and objectives of the project into specific systems requirements. The findings of the previous phase are analysed by the smart glass AR app developer experts and User Experience (UX) researchers who then finalise the requirements for the conceptualisation phase.

Function analysis and allocation are traditionally defined as the first step towards design conceptualisation. A function analysis involves determining the basic functions that need to be performed to accomplish the job. It does not specify who will do them or how they will be accomplished. A function allocation is then performed by the smart glass AR app developer experts and UX researchers that specifies how each function will be done [19].

Storyboarding and wireframe design are the techniques that were used to conceptualise the design in the form of user interface elements. The final step in the feature mapping stage is to design the final UI of the smart glass AR application. It is almost impossible to test all potential designs to discover their shortcomings from the standpoint of usability.

The time and expense of such a proposition are managed through the application of a well-developed set of human factors principles and design guidelines that allow designers to avoid many pitfalls in that design process. During the course of this work, high fidelity mockups based on finalised elements in the previous step are merged with the design knowledge obtained from the literature [7], [17-18], [20-22].

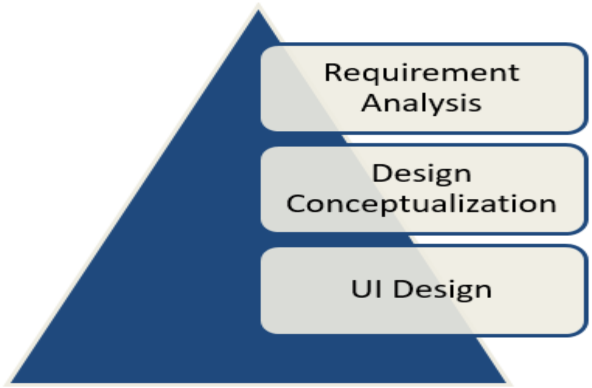

Figure 2: Feature Mapping Process

C. Proof of Concept Development

RAD methodology as shown in Figure 3. [23] is an agile development technique, and in software development, it is a concept that was born out of frustration with the waterfall software design approach. The waterfall software design approach too often resulted in products that were out of date or inefficient by the time they were released. The term was inspired by James Martin, who worked with colleagues to develop a new method called Rapid Iterative Production Prototyping (RIPP). In 1991, this approach became the premise of the book RAD [23].

Martin's development philosophy focused on speed and used strategies such as prototyping, iterative development, and time boxing. He believed that software products can be developed faster and of higher quality through: gathering requirements using workshops or focus groups, prototyping and early reiterative user testing of designs, the re-use of software components, a rigidly paced schedule that defers design improvements to the next product version and less formality in reviews and other team communication [23-25]. RAD is used in the context of this work to quickly design, build and implement a proof-of-concept smart glass-based AR tourism application. Therefore, RAD has been selected as the most appropriate development methodology for the implementation of a smart glass-based AR application development which can be used for the final evaluation of the proposed acceptance model.

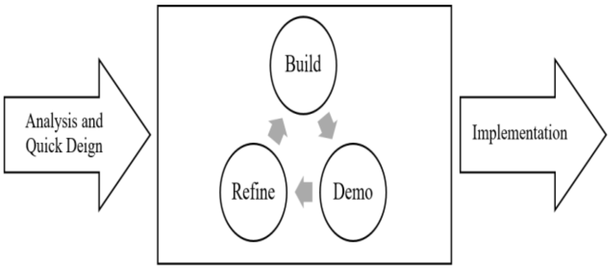

Figure 3: RAD Methodology

III. TECHNICAL REQUIREMENTS

In order to create an AR system, the basic requirements are; a camera to get the live video feed, a compass to get device coordinates, a computational unit to compute the tracking, registration and rendering tasks and a display to show the augmented contents[4], [26]. In a normal AR application, the camera detects the target image and computational unit is used for processing the image for visual output. In the case of AR browsers or navigation-based AR, however, a compass readings and users current location from a GPS sensor is used along with the camera feed to render the augmented contents. The display is used to present the virtual content on top of the real world. To develop such systems, a number of hardware and software platforms are used. The following are the specific hardware and software specifications used to develop the TouristicAR prototype for cultural heritage tourists.

A. Smart Glass Hardware

The conceptualisation of this work started in late 2015 when the commercialisation of the smart glass was in its initial phase. [27] suggested that smart monocular glasses were found most suitable for consumer-related applications compared to smart binocular glasses which were found suitable for specific industrial applications.

The most reliable smart glass options available at the time were "Google Glass Explorer Edition" by Google and "Vuzix M100" by Vuzix. Both products were identified as suitable for the development of location-based AR applications availability of a processing unit, adequate memory, and presence of required sensors and display.

A survey was conducted to compare the features of both the products side by side to find a better option in the context of this work. Also, due to high unpredictability with the performance of these products various online review blogs were used to make a final decision on the selection.

Table 1 [1] presents the differences between the products in a side-by-side comparison. The comparison revealed the differences between the two products Google Glass was found to have a better CPU with higher ram and better storage options. The battery of Google Glass was also found to outperform the Vuzix M100 by a slight margin. Both products have Bluetooth and Wi-Fi connectivity which allows them to get context-aware data from internet rich data sources instantly. The reviews also showed a liking towards Google Glass compared to Vuzix M100 and suggested that Google Glass is a far more reliable option and has better documentation for the developers. As discussed in the previous work visual appeal is an important factor for the acceptance of augmented reality the Google Glass Explorer Edition came in with some colour options and has a very sleek and modern look and feel to it. It was found more visually appealing than Vuzix M100. Therefore, in the context of this is work Google Glass was selected as a platform to develop the Smart glass augmented reality prototype application for cultural heritage tourists.

Table 1
Smart Glass Comparison

Specification	Google Glass Explorer Edition	Vuzix M100
Hardware Look		
CPU	OMAP 4430 SoC, dual-core @ 1GHz	OMAP4460 at 1.2GHz
Memory	2GB	1GB
Storage	16 GB Flash total (12 GB of usable)	4GB flash, 32GB with MicroSD.
Battery	570 mAh lithium-polymer battery.	550mAh rechargeable internal battery, Up to 6 hours of usage.
Display	Prism projector, 640×360 pixels	6:9, WQVGA, full-colour display with 428 x 240 resolution.
Camera	5MP photos, 720p video.	5MP photos, 1080p video.
Sensors	Accelerometer, gyroscope, magnetometer, ambient light sensor, and proximity sensor.	3 DOF gesture engine, Ambient light, GPS, Proximity, Accelerometer, gyroscope, magnetometer, ambient light sensor, and proximity sensor.
Connectivity	Wifi and Bluetooth.	Wifi and Bluetooth.
Sound	Bone conduction transducer, earbuds, and microphone.	Ear speaker and a noise-cancelling microphone
Controls	Touchpad, app and voice.	4 control buttons, app, voice navigation and gestures.

B. Smart Glass Software

It is very difficult to achieve the development of an industry standard prototype without a good design and programming software. During the course of the work, a number of programming and design software along with coding libraries were used to develop the Smart glass app. The smart glass prototype application is built on the Android platform, and therefore the coding is done primarily using JAVA language. Adobe Photoshop, Adobe Illustrator, Glassware flow designer and much other software are used for designing the prototype. The most important software and toolkits used in this work are mentioned as the following.

1) Android Software Development Kit

The Android software development kit (Android SDK) includes a comprehensive set of development tools for the development of applications on the Android platform. These set of developmental tools include a debugger, libraries, a handset emulator based on QEMU, documentation, sample code, and tutorials. Currently supported development platforms include computers running Linux, Mac OS X

10.5.8 or later, Windows XP or later. Enhancements to Android's SDK go hand in and with the overall Android platform development. The SDK also supports older versions of the Android platform in case developers wish to target their applications on older devices. Android applications are packaged in .apk format and stored under /data/app folder on the Android OS. To develop the applications for Google Glass using Android SDK, an additional Google Glass Development Kit (GDK) has to be used. This set of libraries provide glass specific code such as glass scroll cards and live cards for glass application development. Figure 4 shows part of the GDK code used in the TouristicAR prototype development.

```
import com.google.android.glass.app.Card;
import com.google.android.glass.touchpad.Gesture;
import com.google.android.glass.touchpad.GestureDetector;

public class SimpleCameraActivity extends FragmentActivity imp
        OnClickBeyondarObjectListener {
    private GestureDetector createGestureDetector(Context cont
        GestureDetector gestureDetector = new GestureDetector(
        //Create a base listener for generic gestures
        gestureDetector.setBaseListener(new GestureDetector.Ba
            @Override
            public boolean onGesture(Gesture gesture) {
                if (gesture == Gesture.TAP) {
                    ontappp();
                    return true;
                } else if (gesture == Gesture.TWO_TAP) {
                    // do something on two finger tap
                    Log.e("onClick", "TWO_TAP");
                    openOptionsMenu();
                    return true;
                }
```

Figure 4: Google Glass Development Kit Code

2) Android Studio

There are multiple ways to approach Android Development, but by far the most official and powerful is to use Android Studio. This is the official IDE (Integrated Development Environment) for the Android platform, developed by Google and used to make the majority of the android apps. Android Studio was first announced at a Google I/O conference in 2013 and was released to the general public in 2014 after various beta versions.

However, prior to its release, Android development was handled predominantly through Eclipse IDE, which is a more generic Java IDE that also supports numerous other programming languages. The Android Studio IDE is free to download and use. It has a rich UI development environment with templates to give new developers a launching pad for Android development. Developers find that Studio gives them the tools to build phone and tablet solutions as well as emerging technology solutions for Android TV, Android Wear, Android Auto and also Google Glass. Therefore, during the course of this work, Android studio is used predominantly as the development software for the smart glass prototype development.

3) BeyondAR

BeyondAR is an open source AR framework designed to offer some resources to those developers with interest in working with Augmented Reality based on geo-localisation on Smartphones and tablets. This framework provides the basis to jumpstart development for geo-location AR apps. It allows the creation of custom worlds around the user's current location and augments relevant location-based information in the form of text and images. In this work, the framework has been implemented on the Google Glass platform, and user-interface has been adopted respectively. In the prototype application, Context-aware data is requested from Google's Places API and rendered through this framework upon user's request. Although this framework is quite limited in its functionality and lacks detailed documentation and support, it was found to be the most suitable augmented reality framework in the context of this work. Figure 5 shows the inclusion of "BeyondAR" library for the TouristicAR prototype development.

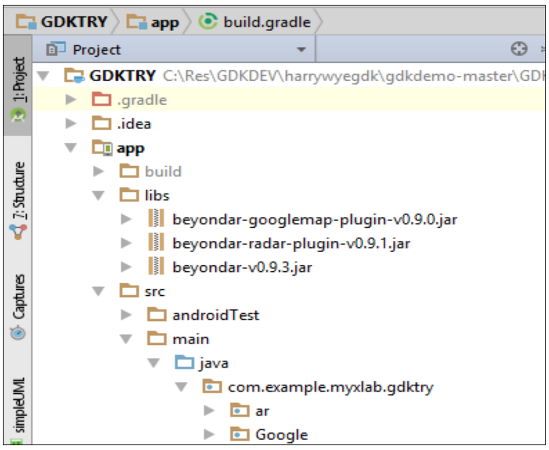

Figure 5: BeyondAR library plugin

IV. Feature Mapping

Feature mapping is one of the most important processes for the development of TouristicAR prototype which truly represents the developed smart glass acceptance model in this research. This process identifies the requirements and conceptualises the design aspect of the smart glass application development. The process is divided into three main stages for simplicity purpose. These phases include; requirement analysis, design conceptualisation and UI design.

A. Requirement Analysis

Requirements analysis is one of the most important phases of the design process. In this phase, it is necessary to translate the broad goals and objectives of the project into specific systems requirements. This analysis includes some different considerations. In the context of this work, however, major requirements are derived from the external dimensions of the developed smart glass acceptance model. Out of the four external dimensions suggested of the developed acceptance model, Information Quality (IQ), Visual Appeal (VA) and Facilitating Conditions (FC) are considered to reflect the most from the application perspective. Technology readiness is primarily dependent on user past sociological behaviour and therefore not considered in the requirement analysis for the development of TouristicAR prototype.

Generally, the designers develop an operational concept that describes their vision for how the proposed system will be used. Such a concept includes the types of missions or functions that should be performed using the system and the capabilities the system should bestow on the user. Such a functional analysis provides important background on the intended use and functions of the system [19].

In addition to the operational concept, at this phase, it is very important to define the environmental conditions in which the system will be used. This prototype application will be used at the UNESCO World Heritage site in the city of Malacca which is crowded and filled with tourists and chirping birds. Hence the noise levels are moderately high. The lighting conditions are generally bright and sunny. Tourists will use the application in a standing or walking position, and their stress level might be high as this may be a totally new technology and interaction system for them. Internet availability on the premise will be required to present context-aware data from Google Places API servers.

The user characteristics are also being identified at this phase. The types of users the system accommodates should are identified along with their pertinent characteristics. The TouristicAR prototype will be used by both the genders of ages 14 and above. Although basic introductory training will be provided before the use of the system by the facilitator, however, the tourists at the UNESCO site are expected to learn the system instructions easily due to their constant interaction with smartphones.

Function analysis and allocation are traditionally defined as the first step towards design conceptualisation. A function analysis involves determining the basic functions that need to be performed to accomplish the job. It does not specify who will do them or how they will be accomplished [19]. A function allocation is performed by the smart glass AR app developer expert and UX researcher that specifies how each function will be done. Similarly, in this work, a functional analysis is performed after reviewing the literature to identify the suitable functionalities which represent the developed smart glass acceptance model dimensions. Table 2 presents the main criteria, functionality and their respective research factors.

Table 2
Feature Mapping Process

No	Criteria	Functionality	Dominant Factor
1	Browse relevant information	Explore functionality provides access to relevant information. Tourist expects to see context-aware, rich and up-to-date information.	Information quality, Facilitating conditions
2	Interactive AR view	The clickable or interactable user interface could serve for more detailed information about a POI	Information quality & Visual appeal
3	Map and Navigation	The ability to navigate to a POI after AR visualisation for a rich experience.	Visual Appeal & Facilitating Conditions

B. Design Conceptualization

The next step in the process of feature mapping process is the conceptualisation of the design requirements. With a firm grasp of the user's needs, requirements and scenarios, design activities can be initiated. A UX expert is consulted in this phase to check the process of designing. Some ideas and application flows are brainstormed during the process. Rough drawings are sketched with pen/pencil and paper or digital tools to identify the needs and motivations of tourists and generate as many ideas as possible to serve the identified needs. TouristicAR prototype wireframes are generated using Adobe XD which are later converted into full-fledged UI designs. The final sketches designed for the TouristicAR prototype are presented in Figure 6.

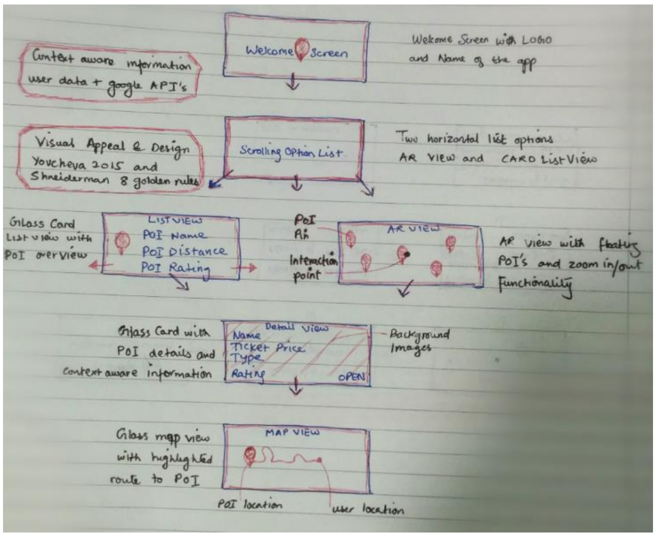

Figure 6: Hand Sketched Wireframe Design

C. UI Design

At its heart, the design is a creative process. User interface (UI) design is no different. There can be many viable ways to design any system that will meet the requirements established. Given the myriad of technologies available and the hundreds of permutations of assignments of display and control requirements to those technologies, designers can generate great variety in resultant design concepts. It is almost impossible to test all potential designs to discover their shortcomings from the standpoint of usability. The time and expense of such a proposition are managed through the application of a well-developed set of human factors principles and design guidelines that allow designers to avoid many pitfalls in that design process.

In this user-based study a special focus is given to Shneiderman's "Eight Golden Rules of Interface Design" [28] and the design principles and guidelines provided by Google for designing Google glass applications.

Ben Shneiderman's eight golden rules are; Strive for consistency, enable frequent users to use shortcuts, offer informative feedback, Design dialog to yield closure, offer simple error handling, permit easy reversal of actions, support internal locus of control and Reduce short-term memory load. All the eight rules are consolidated in the final UI design of the prototype.

It is important to note that Google Glass is fundamentally different from existing mobile platforms in both design and use. Therefore, Google has also recommended five glass specific design principles which are considered during the UI design process of the TouristicAR prototype. These design principles are; design for glass, don't get in the way, keep it relevant, avoid the unexpected and build for people. To create the initial UI design, Google's glassware designer application is used. The resultant UI design and flow are presented in Figure 7.

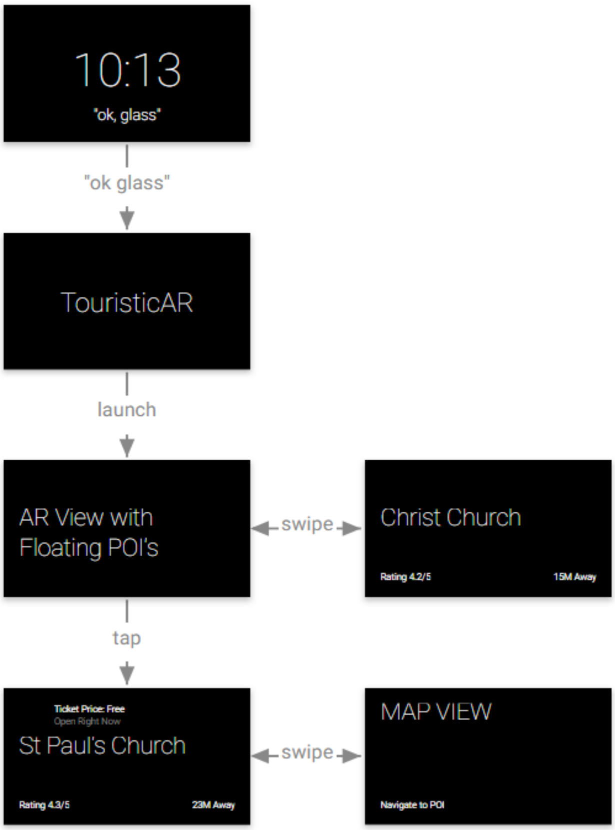

Figure 7: Glass App UI Design

V. Prototype Development

Rapid prototype development is the final and the most important phase of the model implementation. In this phase, the user interface design is converted into a working TouristicAR prototype which can be used for the evaluation of the developed model. The development of this prototype is based on RAD methodology. The architecture of the TouristicAR prototype as shown in Figure 8 is divided into two main modules; the main AR module and a supporting Glass module. The AR module is responsible for producing the AR view whereas the Glass module supports the presentation of non-AR views such as the glass card views and map view. The AR module is further divided into two main sub-modules. The first sub-module is called context-aware AR engine

This sub-module is responsible for making sense of user's predetermined data, acquire users' current location through either a GPS sensor or Google Play Services fused location API and finally requested the context-aware data from Google Places API based on the user's current location. The REST API request is as follows:

https://maps.googleapis.com/maps/api/place/nearbysearch/json?location=2.194403,%20102.248696&radius=500&type=place_of_worship|museum|art_gallery|church&key=(your API key)

It fetches response based on three major types of Point of Interest (POI's) that include place of worship, museum, and art gallery. The requested context-aware information contains the POI name, POI description, POI id, POI Ratings, POI opening hours and POI type. The second sub-module is called AR Rendering engine. This sub-module is responsible for generating the AR view. This sub-module receives the information from the context-aware AR engine and combines it with the compass sensor readings. This data is then combined with a predefined POI design found suitable for smart glasses by cultural heritage tourists in the preliminary study. The POI design for AR environment is created based on the guidelines and principles suggested by [18], [20]. Finally, this combined data is added to the live camera feed to generate an enhanced Augmented Reality view. Following the design guidelines and design principles, the prototype application also has a supporting non-AR view which shows nearby POI's in the form of a scrollable list of Google Glass card elements.

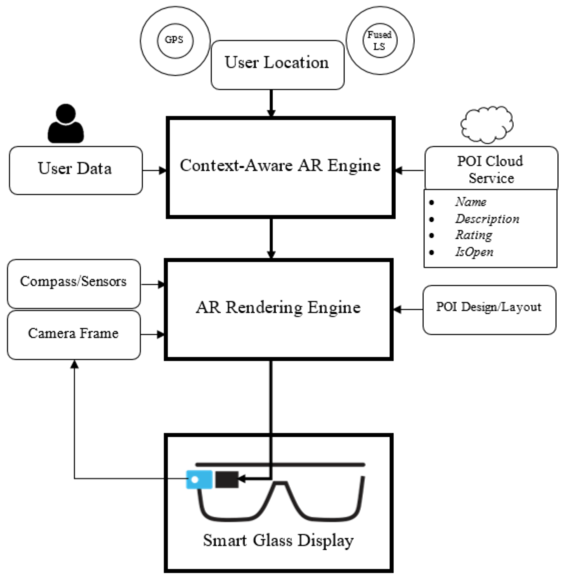

Figure 8: System Architecture of AR Module

The workflow of the TouristicAR prototype revolves around three main functionalities. The first functionality is the explore functionality where the tourist is allowed to explore the nearby relevant POI's. The second functionality allows them to tap on any selected POI to see more context-aware information related to the POI. The final functionality allows tourists to navigate to the selected POI on a map view. To interact with the user interface, google glass touchpad is used. Single tap at the touchpad takes the user to the next operation, double tap opens up any available option menu, and the left and right swipes allow users to scroll through different options respectively. The workflow of the TouristicAR prototype is guided by the options presented at the start of the application.

In the first workflow (Figure 9), after welcoming splash screen, the users select the AR view option. The user is directed to an AR view where he/she can see floating icons around him. Each icon represents a distinct UNESCO World Heritage site POI. At the top of the screen, the user can find a representation of the touchpad which highlights the finger movements on the touchpad. This view also supports zoom in/zoom out for increasing/decreasing the POI sizes and distance from the user. At the center of the screen, there is a stationary red dot which acts as a pointer for tapping and selecting on a floating POI. Once a floating POI is selected, a detailed view is shown with the context-aware information of the POI. The user then has an option to double tap the touchpad and select navigate to see the route between him and the POI on a map view.

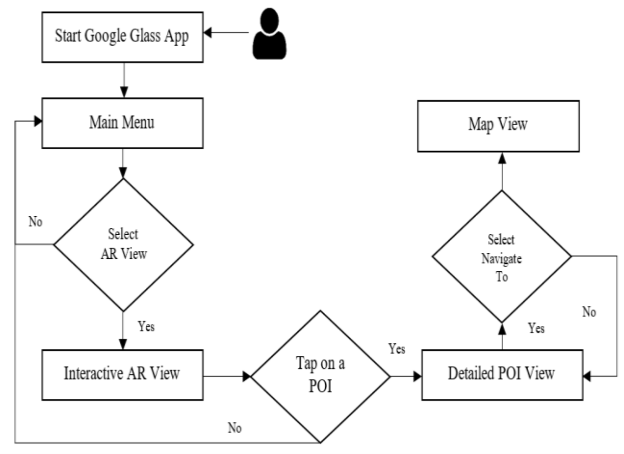

Figure 9: First application’s workflow

This view also supports zoom in/zoom out for increasing/decreasing the POI sizes and distance from the user. At the centre of the screen, there is a stationary red dot which acts as a pointer for tapping and selecting on a floating POI. Once a floating POI is selected, a detailed view is shown with the context-aware information of the POI. The user then has an option to double tap the touchpad and select navigate to see the route between him and the POI on a map view. In the second workflow, however, after the welcoming splash screen, the users select the Glass List view option.

Figure 10: Final UI Implementation

The user is directed to a scrollable list of cards stacked beside each other. Each card represents a distinct UNESCO World Heritage site POI. Each card shows abstract information regarding the POI. The POI's are listed in accordance with their nearness to the user's location. Once a card is selected, a detailed view is shown with the context-aware information of the selected POI. Similar to the first workflow the user then has an option to double tap the touchpad and select navigate to see the route between him and the POI on a map view. Figure 10 shows the final UI implementation of the TouristicAR highlighting the components that represent visual appeal and context-aware data (information quality).

VI. CONCLUSION

The developed AR smart glass acceptance model for cultural heritage tourists should be validated with tourist's interaction. This work, therefore, provides the steps to implement the model in the form of a TouristicAR prototype which can be used by the tourists. This work gives an overview of the development platforms used during the implementation process. The use of hardware and software devices and tools such as Google Glass and Android SDK is justified in this work. Also, the most important process of model implementation which is called feature mapping is discussed in this work. This includes the requirement analysis, the design conceptualisation, and the final UI design. Finally, this work discusses the prototype development of the smart glass AR application using a rapid prototyping methodology called RAD. The prototype application represents the various factors highlighted in the developed acceptance model. In addition to measuring tourist satisfaction for smart glass AR tourism at cultural heritage sites, this novel application can also be used to validate the acceptance model developed by [2] through PLS-SEM based regression analysis.

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