Glass4Tourism: A wearable human interface for tourism

Joana Gaspar Lopes
Electrical and Computer Engineering, Instituto Superior Técnico, Universidade de Lisboa
joana.g.lopes@tecnico.ulisboa.pt

Abstract—**Tourism is an industry in constant growth and evolution, in which technology has a great impact. There are hundreds of tourism related mobile applications for tablets and mobile phones, from transportation, to flight or hotel bookings, to tour guides, although the implementation on wearable devices, such as smart glasses, is very little explored. Since the announcement of Google Glass in 2012, these devices have received more media attention, both for the possibilities they present and for the downsides that may occur, such as lack of privacy. However, no outdoors tourism solutions surfaced since then, which could offer a commercial advantage for tourism operators, enabling the tourists to explore a new destination with all the required information available at a glance. Thus, this dissertation proposes to investigate that concept, implementing an application in a head mounted display (HMD) that guides the user through an outdoors tourism route. Among several options, the device chosen for the proof of concept was Recon Jet, mainly due to functioning independently from a mobile phone. The results show that, despite the verified potential of the concept, the existing technology is not yet developed enough for this kind of application. The evaluation was conducted by means of a questionnaire to the participants, who tested the solution.**

Keywords—**HMD, Tourism, Mobile Application, Smart Glasses**

I. Introduction

The curiosity to travel and learn about new places and cultures is one of the motives that drives people to leave their homes and places that are familiar. Overtime, this led to the development of tools to aid in the process of visiting a foreign place. According to the World Tourism Organisation, ”Tourism is a social, cultural and economic phenomenon which entails the movement of people to countries or places outside their usual environment for personal or business/professional purposes. These people are called visitors (...) and tourism has to do with their activities, some of which involve tourism expenditure.” [1]. Tourism is nowadays one of the fastest growing economic sectors in the world and the world's third largest export category [2], which justifies the need to keep investing in this sector. Using the technology available today, it is possible to innovate and discover creative forms of attracting and supporting tourists, and one of the possible approaches for this innovation is through wearable technology, or wearables, although their presence in the market is still reduced.

The announcement of Glass, by Google, in April 2012 and its launch in April of the following year [3] drew attention to the glass-like type of wearables, head mounted displays (HMDs) that project a screen in the user's field of vision, creating a hands-free experience. This type of device has potential applications in multiple fields and tourism is not excluded. Enjoying a tourism activity and, at the same time, being able to record and share the experience or have extra insights about the surroundings are potential advantages. For instance, wearing an HMD that allows image and video capture has the potential of making the experience even more enticing, as it offers the possibility to capture the scenario without interrupting the experience by holding a camera.

This project was developed in a company that already provides technological solutions to operators of the tourism sector. One of those, Boost, is a tablet and smartphone application that facilitates outdoors tourism and team building activities. This application belonged to and was managed by a tourism operator. The proposal was to adapt Boost to a glass-like wearable in partnership with the mentioned tourism operator, testing and evaluating the final prototype with their customers. This application is, instead, a tool to be configured by the tourism operator and used by its customers. However, during the course of this project, due to business decisions, the tourism operator ceased being a client of the company, making the planned testing non-viable. The concept was still tested, although by volunteers in a testing location, instead of by tourists in a real tourism tour.

In the past few years, the market of HMDs has suffered only minor updates and no new solutions or studies with applications for outdoors tourism using these devices were developed. Thus, despite the aforementioned hindrance and the delay, due to professional reasons, since the original proposal, the study of such a solution remains nonetheless pertinent.

The goal of this work is to implement and test an outdoors tourism application, Glass4Tourism, based upon Boost in an HMD device, studying its impact, benefits and disadvantages. Boost has two components, the back office (BO), where the tourism operator defines all the contents of the tourism experience, and the mobile application, which uses those contents to guide the user through a route. The focus of this project is solely the mobile component, with the back office structure being used as is. In summary, the main functionalities of Boost are: receiving as input a set of previously created routes, each consisting in a set of points and activities associated with each point; guiding the user to follow that route; launching the activities at each route point; allowing the exchange of messages between the application user and a monitor with access to the BO.

Besides complying with the aforementioned functionalities, the glassware application developed during this project, Glass4Tourism, should also explore what new possibilities are permitted by the new device. The goal is to complement the solution with new enriching features and to remove existing ones that are not adequate for an HMD device. An enhancing element to be explored is augmented reality (AR), which allows to superimpose information on the user's field of vision.

Following this introduction, section II introduces the state of the art of HMD devices and its applications, as well as the presence of technology in the context of tourism. In section 3, an explanation of the functional and technological architecture is provided, followed by the description of the implementation and in section IV. The testing use cases and the criteria used to evaluate the project, as well as the results and corresponding discussion, are presented in section V. Finally, section VI presents the conclusions and suggestions for future work.

II. State of the Art

The purpose of this work is to develop an application to be implemented on a glass-like wearable device for outdoors tourism, thus it is of essence to learn what technologies are available, what already exists and how are people reacting to tourism oriented technological solutions.

This section covers the research of available HMDs and the choice of the device used for the proof of concept. Afterwards, it is assessed the present and past presence of smart glasses in tourism, followed by a comparison of both commercial and research mobile tourism applications.

A. HMDs

An HMD is a particular case of wearable technology, a device that projects information into the user's field of vision and can be made to react to head and body movements [4]. There are several names to reference this type of devices, such as head-worn displays, heads-up displays (HUDs), or smart glasses. Their current version usually consists of a glass-like device projecting a screen or an image in the user's field of vision, with the physical structure, type of display and general functionalities varying depending on the manufacturer. HMDs can either be monocular or binocular, see-through or opaque.

These devices are not a new concept, a patent for a monocular head-mounted cathode-ray tube viewer was registered in 1963 [5] and a head-mounted three dimensional display was created in 1968 [6].

The possibilities of HMDs have greatly expanded in the past decade, bringing both positive and negative aspects. Generally speaking, a device connected to a smartphone that can display e-mails or incoming calls in front of the eyes, take pictures, perform online searches, etc. presents an efficient solution. And it can be applied in a wide range of areas, from health care and surgery to firefighting and ludic purposes.

Despite all the possibilities that HMDs have to offer, it is of essence to identify its potential impact, to understand how it is perceived by the users and what consequences its use might have. One of the first complains the launch of Google Glass generated was the lack of privacy, people using it to record, take pictures or film unknowingly to those who surround them raises concerns from being filmed while having a conversation with someone wearing Glass to a real-time 24 hour vigilance of the whole world [7]. Engaging with a person wearing smart glasses may present a challenge, and the wearer himself might feel socially uncomfortable. As HMDs represent a major evolution when compared to prior technologies, a study on the psychological mechanisms that lead to the adoption, or not, of this technology revealed that expected peer evaluations of its use are much more likely to influence an individual's use of smart glass, when compared to the use of less visible wearable technologies [8].

The other major concerns involve the distractions caused by driving or even walking with an HMD computer, and the discomfort or blockage of the field of vision that may occur. A study on how HMDs affect task performance and motion concluded that a person's natural performance can be critically altered both on moving and in the task they are performing in the HMD, due to the human difficulty to process information from two sources at the same time. Hence, visual tasks that involve constant monitoring of the device should be avoided [9].

Another concern related to monocular HMDs is the ophthalmological effect of having a screen constantly in front of one eye, leading to asymmetries in what is perceived by each eye. It has been suggested to result in visual difficulties, such as binocular rivalry [10], depth of focus [10, 11], eye movements [10, 11], eye dominance [10], etc.. Increase of eye strain, eye heaviness, eye dryness, brain clarity, sleepiness and body weariness were also associated with the use of HMDs [11]. For the utilisation of HMDs during short periods of time, studies concluded the eyes are not permanently affected [10, 11], although a prolonged use of such devices is not advised.

The purpose of this work is to create a tourism application with activities that would not last more than one day, implying the use of an HMD for a few hours and not repeating its use in a near future. Therefore, although contemplated in the evaluation, worries about long-term health implications are not expected due to the short term use. The privacy issue is also diminished, as it also mitigated by the short-term usage, and it is not to be connected to a personal smartphone and whatever content recorded by the device would of the responsibility of the tourism operator in charge of the tour. However, the issue of performing tasks while using an HMD should be addressed by taking into consideration by creating a simple and functional application, with an interface that has minimal interference with the user's environment and his motion.

B. Available HMD Technology

A total of 8 devices were considered and analysed for use in the proof of concept, many of them still in a developing or early production stage. Devices released posteriorly to the acquisition of the device used in this work were not considered as an option and, thus, are not included in that number. However, the main improvements in the newer models are related to technical specifications of the devices, such as better central processing units (CPUs) and cameras, more storage and random-access memory (RAM) memory, etc., but the usage and main functionalities remain the same, and even the design has not had a remarkable evolution.

The devices were compared according to the following criteria: connectivity options (whether the device has network, Wi-Fi or bluetooth connections), Global Positioning System (GPS), display size, resolution and location of the screen, input methods, speakers, camera, video and audio features, storage, memory, processor, operating system (OS), autonomy, integrated sensors, maps availability, price and weight.

After collecting data on the possible solutions available, the 4 devices chosen as better fitting this solution were Google Glass [12], Recon Jet [13], Optinvent ORA [14] and Vuxiz M100 [15]. Recon Jet was chosen due to its autonomy (4 – 6 hours), price ($499), having GPS, being oriented towards outdoor activities and functioning independently from a mobile phone. The downsides of this device are that it is not see-through, it cannot be wore on top of other glasses, the display has a low resolution and it is too bulky.

C. HMDs in Tourism

On February 2013, Google held a contest which consisted in using the tag #ifihadglass in a post, describing what use the author would give to Glass. From the answers to this contest, a study concluded that one of the main reasons people would use Glass in a tourism or travel application would be to share the experience in a first-person point of view [16]. This findings agree with a study which states the main motive for young international tourists to use their mobile devices while travelling is to "take pictures" and "connecting to social media" [17].

HMDs presence is found mostly in research projects or pilot programmes, and as a particular case in one commercial solution. In the Royal Ontario Museum, through the usage of the META smart glasses, the visitors were able to see cultural artefacts within the museum's "Ming Tomb" [18], and a study using AR in Google Glass in the Manchester Art Gallery found that users were able to quickly adjust to the interaction method of Google Glass and perceived the device to enhance the experience [19].

The commercial solution is GuidiGo [20], which provides a tool for the creation of a tourism route, that is intended for the route's author and not for the final user. In the end, it is possible to compile for Android, iOS, and Glass. The Fine Arts Museums of San Francisco tried a Glass application in a Keith Haring's exhibition, adding extra information when needed, "revealing stories within art work", allowing visitors to notice particular details and to access additional content through AR when approaching an artwork [21].

D. Mobile Tourism Applications

Whereas HMDs have a slow growth rate, smartphone applications are an exponentially growing tool in the tourism business. Electronic tourism guides applications, both from commercial applications and research projects, were analysed to extract the most relevant features. A sample of 6 applications was chosen for comparison both from Google's PlayStore and Apple's AppStore, consisting of the top five applications from each of the stores. By March 2, 2018, the results according to this criteria were: World Travel Guide (Android)/Triposo - Your smart Travel Guide (iOS), by Triposo, Thomas Cook Travelguide (Android and iOS) by Thomas Cook Touristik GmbH, Guides by Lonely Planet (Android and iOS), by Lonely Planet, PocketGuide Audio Travel Guide (Android and iOS), by PocketGuide Inc., World Explorer - Travel Guide by Tasmanic Editions (Android and iOS), tripwolf - Travel Guide & Map (Android and iOS), by tripwolf, Paris Travel Guide (Android) / Paris Travel Guide and Offline City Map (iOS), by Ulmon GmbH. Boost and GuidiGO [20] are also included in the analysis.

In research literature there is also a vast number of published articles proposing mobile travel guide applications, of which the following 8 were reviewed: A mobile 3D-GIS hybrid recommender system for tourism & Route and Map Features [22], Context-Aware Points of Interest Suggestion with Dynamic Weather Data Management [23], iTravel: A recommender system in mobile peer- to-peer environment [24], Mobile Application for Guiding Tourist Activities: Tourist Assistant – TAIS [25], A Mobile Tourist Guide for Trip Planning [26], Mobile application to provide personalized sightseeing tours [27], MyTourGuide.com: A Framework of a Location Based Services for Tourism Industry [28] and World Around Me Client for Windows Phone Devices [29].

It is worth mentioning that all existing similar solutions may not have been discovered, particularly in the case of commercial applications whose client is not the general public. From all the features of tourism applications studied in this section, context awareness, maps, content update, functioning offline, and route tracking are relevant in the context of this project and were taken in consideration during development. Also, sharing the experience from the user's point of view seems to be one of the motivations of the early adopters of Glass, thus, it was contemplated while developing the application. Features such as recommendation systems or route planning are very interesting in the tourism area, however, they are not applicable to the context of this work.

III. State of the Art

The solution proposed in this work relies on external services to provide its content. All those contents are manually inserted in the BO, a web interface created for the purpose, stored in a database in a server, and, later provided to the application via web services. Fig. 1 shows a schematic of this communication BO UI (user interface) - server - application.

The front-end BO and the web services to retrieve the information were already implemented and being used in several commercial applications by the date this work started. The BO platform and web services will be used as-is.
This section introduces the concepts defined in the BO, on which Glass4Tourism relies, and describes the main functionalities of the application, along with the technical specifications of the server, the application and the Jet glasses.

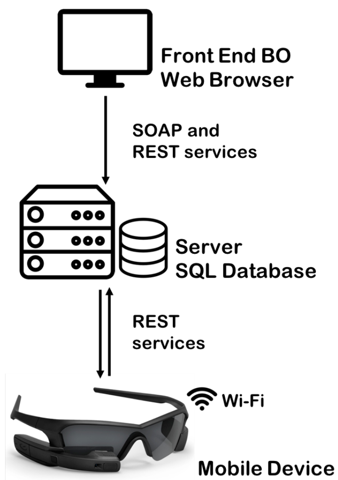

Fig. 1. The data is inserted via a front-end BO in a web browser, stored in a SQL database in a server, and then retrieved by the mobile application through specific requests to that server.

A. BO

The BO is accessed via a web browser and is the graphical interface in which the tourism operator inserts all the required data for the application to function properly., including translations for all these contents. Using this platform, it is also possible to exchange messages with the tourist. It is worth mentioning that this platform is not exclusive for Boost, it is also used with other applications, thus some of the properties of the main concepts are not applicable in this context. The relevant menus of the BO for this work are: points, activities, routes, roadbooks, messages, and translations.

A point is simply a geographical location, it can be of the types route or activity. The first is meant to be visible to the user in the path of the route, whereas the second is not meant to be visible in the route but to unlock a set activities, either by location or by quick response (QR) code reading.

A route activity is an activity to be performed during the tour, it can be of one of 4 types: multiple choice answer, instructions, challenge, and QR code.

A route is a collection of points and activities. The points are added to a route in a given order and the activities are added to a point in the same manner. It is also possible to draw a route path, defining the path between points.

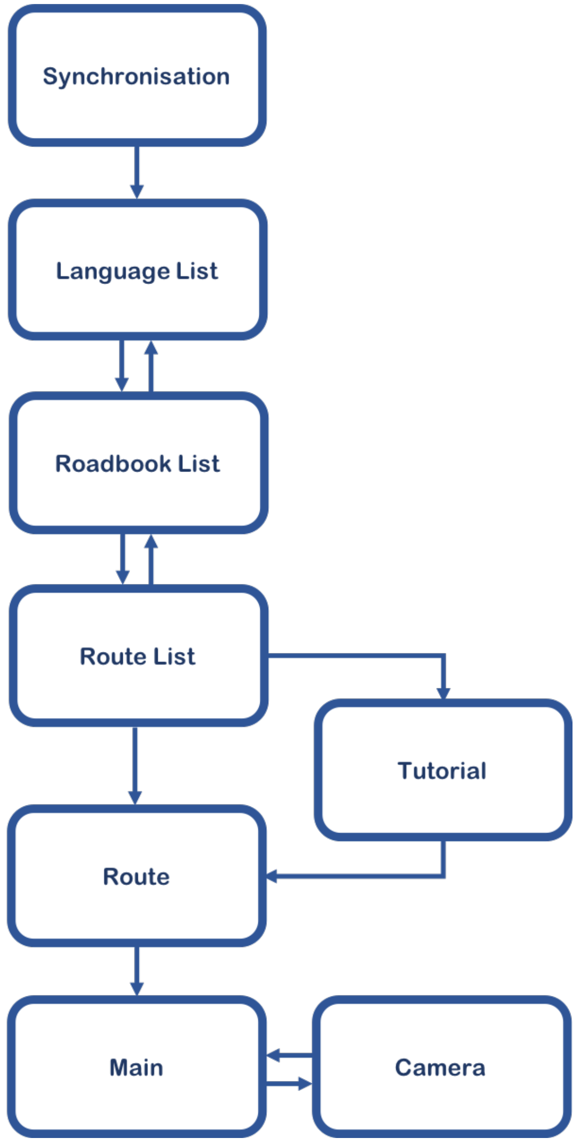

Fig. 2. Structure of Glass4Tourism

Roadbooks are simply collections of routes, the and translations menu allows to define which languages are available and to effectively translate the contents of points, activities, routes and roadbooks.
The BO also offers the possibility to exchange messages with the user of the application, with a chat UI to view the conversation history.

B. Glass4Tourism

Glass4Tourism relies on web services, the responses of which contain all information previously introduced in the BO, to show the contents. As with the BO, the webservices are not part of the scope of this project and were used as-is.

The application developed in this project should possess the following functionalities: communicate with the server to receive roadbooks, routes, points, activities and translations; allow the user to choose a language, from the options introduced in the BO, and present all contents in that language; give directions to the user to follow a route from point to point; display the activities associated with each point and allow the user to complete them; allow the user and a monitor of the tourism activity to communicate through the BO.

It was decided to build the application as stand-alone in Recon Jet, making it independent of a mobile phone, for the commercial advantage of requiring only one device, not due to restrictions of the device, since it supports connection and provides application programming interfaces (APIs) for communication with mobile phones.

To facilitate the user's interaction with the device, a tutorial with the controls used during the route should be always available before starting the tour. During the tourism tour itself, it should be easily available at all times a map, a view giving directions between points, and a chat view to exchange messages with a tour monitor, with access to the BO. Camera functionalities should also be always available.

Another feature commonly associated with HMDs is AR. However, the display of Recon Jet is not see-through and it is not at eye-level but below and to the right. Therefore, the only option for AR, from the device's standpoint, would be to have the camera on during most of the tour, which is not feasible due to autonomy restrictions. On the other hand, the BO is not prepared to introduce information that would work with AR seamlessly throughout the tour. As a midway compromise, AR should be used only upon the arrival at a route point, using the camera, the location, and the orientation of the user, to show the name of the route point when the user is oriented towards it. The success of this approach is subject to the resolution of the camera and to the accuracy of the location and orientation.
The resulting structure of the application is presented in Fig. 2, where Main represents the core of the application, where the users will be guided through the points and activities of the route.

C. *Technical Architecture*

Jet runs a modified version of Android (mobile OS developed by Google) 4.1, ReconOS 4. The programming language used in this project was Java, the standard language of the Android software development kit (SDK) and also the language of Recon's SDK. The Android SDK includes a wide range of libraries oriented for mobile programming and the Recon SDK includes tools, documentation, and samples necessary to write third-party applications for Jet. The Recon SDK extends the Android SDK with extensions specific to Recon's devices hardware, providing APIs that allow the developer to take advantage of the features of the device, such as the heading API, the Recon UI API, or the glance API. For the location features of the application, the device's built-in GPS is used, employing the native Android API to receive location updates.

One of the limitations of Recon's SDK is that it does not have an API to interact with its maps. ReconOS does have a native maps app, and it is possible to open that app from a third-party application, however, the only customisation possibility is to open the map in a given location. Google Maps, Android's native maps, that do have an API that offers the mentioned features, is not an option, as it requires Google Play Services to be installed on the device, not available in Jet. This limitation implies that the directions from point to point in the tour could not be given with the visual aid of a map.

All technical specifications of Jet are displayed in Table I. The Bluetooth capacity of the device was not used, nor the altimeter, barometer and thermometer sensors.

All the roadbooks, routes, points and activities defined in the BO, as well as the relationships amongst them, are available through Representational State Transfer (REST) web services, the answers of which are in JavaScript Object Notation (JSON) format. There are services to receive and send messages, as well as a service to update the messages status of a specific message.

The data introduced manually in the BO is stored via Simple Object Access Protocol (SOAP) and REST web services in a database, using Microsoft Structured Query Language (SQL) Server 2008 R2, in a server running Windows Server 2008 R2, SP1, and the web services that consume information from that database to generate the JSON responses run on the same machine. To make requests to these web services, Jet connects to the internet via Wi-Fi. Thus, to exchange messages during the tour, an Wi-Fi connection is required.

IV. Implementation

In this section, the details and challenges implementing the application in Jet are presented. First, it is explained the design constraints and guidelines while developing for device that is new, not yet very explored, and with limited screen capabilities, followed by the presentation of the resulting application.

A. *UI Design and Usability Constraints on an HMD*

The UI and the user experience (UX) were carefully thought so that the adaptation of a user to Jet is as easy and possible.
For whatever kind of device or application, the first references to be taken in consideration are Nielsen's heuristics [30].

On smart glasses specifically, a master thesis dwelling on design principles for glassware UI, based on Google Glass, formulated the following guidelines: to plan carefully how information is presented; to make all visual elements serve a purpose; to use icons only for supplementary information and to use existing, well-known icons; to avoid central alignment and filling the screen in a uniform block; and to not use muted tones, if using colour [31].

The design guidelines by Recon suggest using horizontal swipes as the primary navigation method, 30-pixel margins along all four sides of the screen, and complying with ReconOS's building blocks, font, font size, colours and icons [32].

Google's design guidelines for Glass, which should be considered as most hold true for many HMDs, recommend focusing on how the device and the services provided can complement each other, offering engaging functionality that supplements the user's life, delivering information at the right place and time, not sending content too frequently or at unexpected or inappropriate times, and designing interfaces that use imagery, colloquial voice interactions, and natural gestures.

From articles about developing applications for smartphones in their early stages, it is clear the challenges then, such as small screens and limited input options, are similar to the ones faced now for HMDs [33, 34, 35]. The following guidelines emerge: appealing UI; short and concise information, interaction should require minimal effort and not distract the user's attention; hierarchical multi-level structure of the application; design menus which to easily reach the desired information; labelling buttons and menus clearly and consistently; avoid long lists of choices; allow the user to finish tasks with minimum interaction with the device; and fit page content on one screen.

B. *Jet Application*

The Android OS is primarily oriented to be controlled with touch inputs, allowing the user to click anywhere on the screen. In Recon Jet, as mentioned, the user has limited input possibilities, which demands less input variations. The main focus during development was to make the application as simple as possible and requiring minimum inputs from the user to function properly.

The core of the application consists of a horizontal swipe list that should be composed by three views: map, navigation, and chat. However, maps were not available, and that view was omitted. Recon does not provide an API to allow direct interaction with their maps, thus it was planned to simply show the map in the user's current location. This would be done opening a third-party application, Recon Maps, yet, by the time of the development of the application, it was no longer possible to download Recon maps.

The colours of the application - black, white and yellow - were chosen to maintain coherency with the colours of ReconOS. The control icons follow the same logic, those already existing were used (select, back, and camera), and the new icons added for this application (vertical scroll and audio playing) follow the same design principles and comply with what is already known by the user.

At all times during the tour, it is indicated what commands are available for each action, and the user has always information about the state of the system, whether it is in navigation or in a point, and there are dialogs confirming all important actions, with indication of which commands lead to what result.

1) *Synchronisation*

The application retrieves the contents introduced in the BO via web services. Those contents are downloaded and stored in a local database. Each time the application launches, the systems connects to the server, verifies whether there are new versions available and, if positive, downloads the contents. An internet connection is only mandatory the first time after the application is installed, otherwise it can function offline with the previously downloaded roadbooks, routes, points, activities and translations.

The main difficulty in the synchronisation process was the assignment of path points to each point of the route. For each route, the service returns a list of coordinates in the well-known text (WKT) format, with no association between these coordinates and the route points.

To assign a path to each point, it is assumed by the system that the list of coordinates is sorted according to the order of the points in the route, and that all points are part of the path and, thus, part of this list of coordinates. The path leading to each route point is the set of coordinates the user must pass to arrive to that point. An algorithm splits the coordinate list and assigns each subset to a point.

2) *Language, Roadbook and Route List*

The first required input of Glass4Tourism is the choice of a language. After choosing a language, all translations of roadbooks, routes, points, and route activities texts for that language are loaded into memory and all the roadbooks with translations for that language are retrieved from the local database.

After a language, a Roadbook and a Route are chosen, there is the option of going through a usage tutorial, explaining the main controls and general functionalities, or go straight to the information about the chosen Route. These initial configurations are made by the monitor of the tourism activity and not by the tourist. When the route is confirmed, all route objects are loaded into memory: route points, activity points and route activities.

The language, roadbook, and route selection use the carousel view from the Recon SDK, a horizontal swipe menu with tabs temporarily visible on top right after a swipe. Fig. 3. shows the route selection menu.

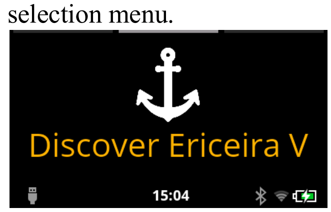

Fig. 3. Screen with the list of routes

3) *Tutorial*

A tutorial was created in order to familiarise the user with the commands of the device before actually starting the route, guiding the user through the commands necessary to use Glass4Tourism: select, back, scroll vertically, double click select to access the camera features and horizontal swipe.
Every time an action is accessible, the respective symbol is displayed in the screen. This tutorial is intended for the tourist user, and not for the tourism monitor user. It is assumed he will have time to acquire himself to the device or receive instruction, so he can help the tourist with any questions during the tourism activity itself.

4) *Route*

After the optional tutorial, the user is presented with an overview of the route. Two types of routes are considered: sequential and invisible sequence. For the visible route type, a preview of the route is presented, in the form of a sorted list of all its points. For the invisible route type, no preview is shown, only a dialog confirming the beginning of the route.

5) Camera

To allow the users to take pictures, make videos or read QR codes at any time during the route, the camera is almost always available via a double click on the select button. The layout of the camera Android Activity was based on the native layout for the camera of the ReconOS and modified to include QR code reading. Swiping horizontally in the touch pad allows to switch between the photos, videos and QR code reader modes.

To take pictures and make videos the native Android libraries were used. The video has a duration limit of 30 seconds, a restriction imposed by the application due to storage limitations of the device. To access the QR code reader, a barcode API was used, allowing to convert the QR code in a string and compare it with the expected QR codes. To be validated, the result text has to comply to the expected formats. This functionality is shown in Fig. 4.

Fig. 4. Camera with QR code reader.

6) Main Activity

After starting a route, the user is taken core of the application, a horizontal swipe menu, also based on Recon's carousel menu. As previously mentioned, the map view had to be omitted, remaining only the navigation on the left and the chat on the right.

The navigation view is the default page, where the user is guided between points, warned when he arrives to a point, and guided through the route activities of each point. Route points can only be accessed by arriving to its location, but activity points can be triggered either by location or by QR code reading.

After arriving to a route point, the AR feature is launched, a camera view which superimposes the name of the route point on the image when the user is looking in its direction. Fig. 5. shows the main components of this section of the application.

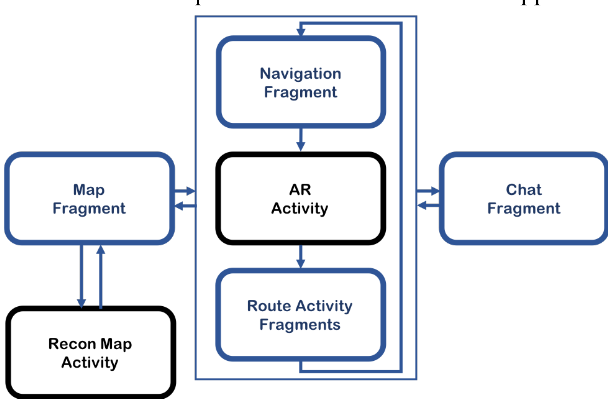

Fig. 5. Sequence of Android Fragments of the Main Activity

When the navigation is first launched, the location, heading and messaging services are started, and all location readings are stored in a file in the device, to later evaluate the accuracy of the GPS. These services use the Android Location API and Recon's Heading API. The battery status at the beginning and end of a route is also recorded, to evaluate the device's autonomy.

A request for new messages is sent to the server every 5 seconds. If new messages exist, a reply is sent to the server acknowledging that those messages are received. Of course, this feature requires an internet connection.

From the user's perspective, the communication is not free due to the lack of a friendly keyboard in the device, the user can either send a predefined or answer the monitor choosing an option from a list provided by the sender of the message, as depicted in Fig. 6.

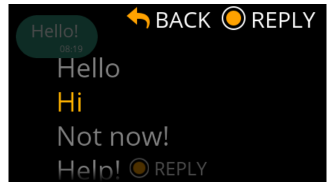

Fig. 6. Options to reply to a message, two de- fault options and three additional from the server.

Every time a new message is received, and the user is not in the messages view, an alert appears, giving him the option to either visualize the message immediately or return to the current activity.

During navigation, the location and orientation of the users are constantly retrieved, to guide the user in the correct direction. The location and heading services feed the view depicted in Fig. 7. and when a location update is received, the current coordinates and motion speed of the user (also returned by the location services) are updated and the distance, time until the next route point and estimated time of arrival (ETA) are recalculated. For every new section of the path, a warning sound is played demanding the attention of the user. The orientation of the arrow is updated on both a location or a heading update, using the most recent value.

Fig. 7. Sequential route: navigation to a route point.

When, by comparing location distances, the system detects the arrival to a route point, the user is informed, and it follows the AR feature, which shows the name of the point when the user is oriented towards it, as displayed in Fig. 8. Here, the current location, yaw and pitch are used.

Fig. 8. AR feature with the device oriented towards the route point and displaying its name.

After the user presses select to start point, the route activities of that point are displayed in order, Fig. 9. displays an example of a multiple choice activity.

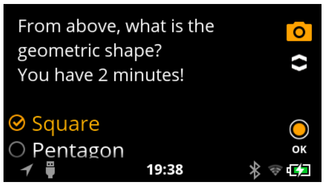

Fig. 9. Activity of type multiple choice, with timer.

After all route points are visited in the defined sequence, the route is finished, and the user is informed. It is mandatory that all route points are visited to finish a route but not that all activity points are. Before finishing a route activity, there is always a confirmation dialog that allows the user to go back if the select button was pressed by mistake, in accordance to the UX guidelines.

V. Evaluation and Results

This section presents the routes used for testing, the volunteers who tested Glass4Tourism and the results of their evaluation. The evaluation was made by means of a questionnaire, with multiple choice questions or classifications in a 5 point scale.

A. *Use Cases and Testers*

Two identical routes, one of type visible and the other invisible, were created to test the concept. The routes had 9 route points and 4 activity points, two of which location activated and the other two QR code activated. Each point had at least one route activity.

28 participants tested the application, with 14 of them testing each type of route. All the users were in the 20 – 39 years old age range, and most of them were between 20 and 29 years old. The gender distribution was approximately even. Of these participants, 11% wear glasses, 21% wear contact lenses and the remaining 68% do not wear any visual aid.

Only 1 user had previous experience with electronic tour guides, and none of them had previous experience with HMD devices. When asked about their attitude towards technology and HMDs in a scale of 1 to 5, 100% and 89% of the users answered 4 or 5, respectively. These skewed statistics make these factors non-viable for comparison. Nonetheless, these statistics mean that negative evaluations about the device or the application are not influenced by a negative attitude towards technology.

An ideal sample of users would be evenly distributed among all these evaluated criteria.

The users were also inquired about luminosity conditions, as it is a parameter that may impact the results. Most of the users, 43%, tested the application with bright sunlight, followed by 21% of the tests in partially cloudy conditions.

B. *Device*

As a general evaluation of the device, 64% of the participants found the device comfortable (classification of 4 or 5) and, in average, male users find it more comfortable. With the device off, 43% of the users found it averagely distracting while walking (classification of 3), with an average of 2.50, with those values increasing to 54% and 3.07 with the device on. The participants found their field of vision nearly equally affected by the device either off or of (2.79 and 2.89 on average, respectively), and, again, male users found their field of vision, on average, more affected by the device, specially with the device on. It was expected from the studies with other HMDs devices analysed in section 2.1 that the device would be distracting while walking and affect the field of vision, and it is for that reason that the routes used for testing did not include any means of transport other than walking and were in roads and paths with little or no traffic.

The results about the screen and display of the device are presented in Fig. 10. The bad visibility of Jet's display, specially in bright sunlight luminosity conditions, is another limitation of the display, as the activities are not, generally speaking, restricted to any particular light conditions. 68% of the participants reported symptoms of ocular or physical discomfort after completing the route, and 100% of those who wore glasses or contact lenses. To lower these statistics, routes of shorter lengths should be evaluated. However, these symptoms are short term and do not impact the long term well-being of the user.

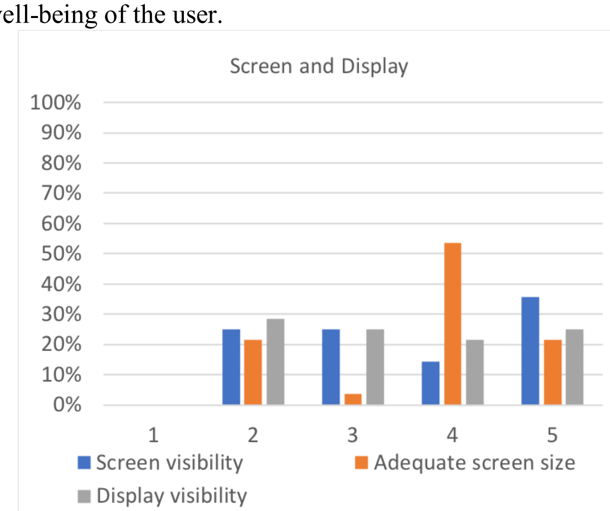

Fig. 10. Testers' evaluation on whether the whole screen is visible, if the display size is adequate, and if it has good visibility, in a scale of 1 to 5.

The 1 hour testing route consumed, on average, 59% of the battery of the device. It was sufficient to complete one route, although it would not be enough for two consecutive routes without recharging the device in between. The accuracy of the GPS is of 3.1 ± 1.7 m in open ground and 6.6 ± 1.0 m between buildings.

C. *Application*

Despite the poor feedback on the device and its inevitable negative impact on the user experience, the results of the evaluation of the application and the overall experience indicate the concept has potential.

64%, 54%, and 89% of the answers were levels 4 or 5 for ease of use, enjoyment, and adequate structure, respectively – Fig. 11. It was verified that the bad visibility of the device is a hindering factor in the users' perception of the application and of the proposed concept, as when considering only the answers of the 10 users who evaluated the screen and display visibility with 4 or 5, 100% of them classified the ease of use, enjoyment, and adequate structure with 4 or 5.

61% of the participants would prefer a similar solution in a tablet or smartphone. This value decreases to 50% discarding the users who had difficulty seeing the display. Still, with half the users preferring a solution in a tablet or smartphone, this solution is not commercially appellative. Nonetheless, 79% of the users stated they would like to repeat the experience in a different route.

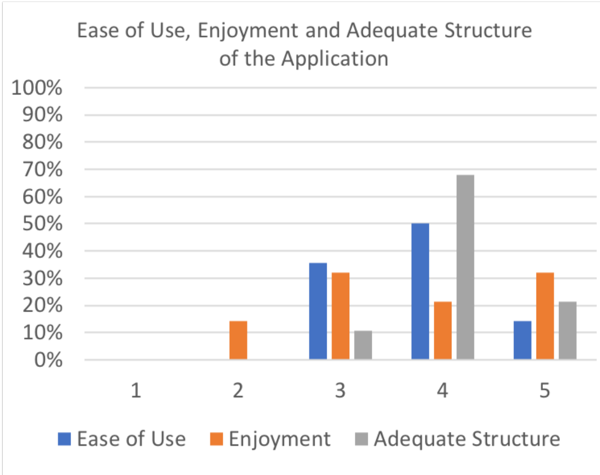

Fig. 11. Participants' classification on the ease and enjoyment of using the application, and on the adequacy of its structure, in a scale of 1 to 5.

The worst classification belongs to the AR effects, with an average of 2.89, and the second worst is the UI design, with an average of 3.04, while the best are the clearness of point arrival and the usefulness of the tutorial, with averages of 4.68 and 4.50, respectively. The evaluation of point arrival and AR effects is displayed in Fig. 12. The poor evaluation of the AR effects is closely related to the GPS accuracy, when a user is standing at a distance of 2 m from, for instance, a fountain, with a GPS error of around 3 m in open ground, the system often shows the name of the point when the user is not oriented towards it, and it oscillates constantly, due to the location updates.

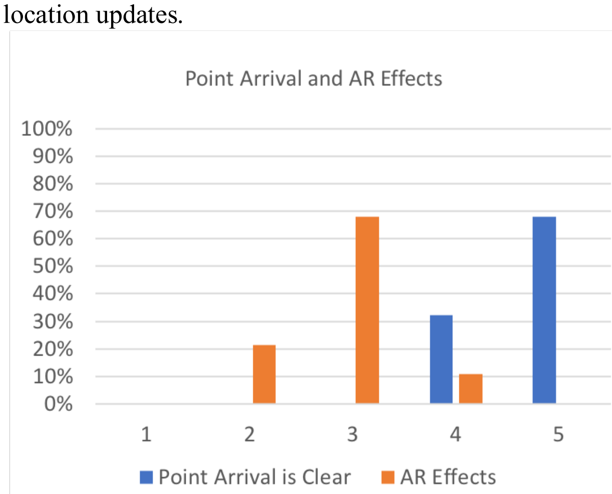

Fig. 12. Classification of clearness of point arrival and AR effects when arriving to a point, in a scale of 1 to 5.

The classification results for the accuracy of route point locations, the orientation between points, and whether the sound effects helped during navigation are presented in Fig. 13. The average evaluations are 3.86, 3.79 and 4.00, respectively. As with AR effects, the navigation and accuracy of point location are dependent on the accuracy and quality of the GPS signal during the route. Each point has a radius defined in the BO to prevent not being found due to GPS errors, which can be adjusted according to the location of the point. However, if that radius is too big, the system may assume it has reached the point before the user is actually at the location, if it is too small, the system may not assume it is in the point at all.

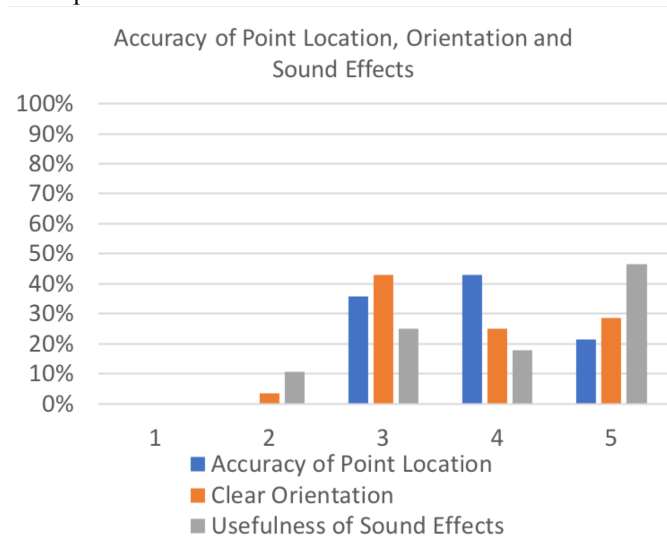

Fig. 13. Classification, in a scale of 1 to 5, of the accuracy of point locations, orientation between points, and usefulness of sound effects during navigation.

The main challenges while performing the analysis of the results were related to the small number of testers and their uneven distribution by the user profile defined in the first section of the questionnaire, making it impossible to filter the evaluation by the users' previous experience with electronic tour guides, for instance, as only 1 user was i this situation. Besides, the small percentage of users who wore glasses or contact lenses made the analysis of the device's effects on user's who required visual aid statistically insignificant. On the other hand, all the volunteers considered themselves enthusiast of technology, thus the results are not impaired by users' preconceptions. It is worth mentioning, the average results of the experience itself depend not only on the limitation of the device and the functioning of the application, but also on the route used for testing and the route activities themselves, which could be richer and more creative.

VI. Conclusion and Future Work

The presented work consisted of an application oriented for tourism and team building activities implemented in an HMD device, and Recon Jet was chosen for the proof of concept. The application guided the user through a set of pre-defined points, with activities in each point. At almost every stage of the application, the user could take pictures or make videos. Since smart glasses are closely associated with AR, and even though this device is not the most appropriate for this use, AR was included in the solution using the camera. To evaluate the solution, volunteers were asked to test the application in defined routes and answer a questionnaire giving their feedback on the device and the experience.

The evaluation showed Recon Jet has several limitations, both on the hardware and software fronts. Hardware limitations are, for instance, that it is too big and it bothers the nose, or that its display is difficult to see in bright sunlight. On the software side, the device imposed limitations on features that are otherwise simple in Android based devices, such as access to a map API.

Even with the limitations of the device, the evidence gathered shows that the concept has commercial potential, as the testers found, on average, the experience with the application enjoyable and most would like to repeat it. However, a few users, even enjoying the experience for being something new and different, commented feeling like an alien on the street while wearing the device, again reiterating the idea that smart glasses technology still has a long way to go. The participants did not take pictures or make videos when not specifically required by the application, despite sharing pictures in a first-person point of view being the predominant tourism related purpose expected for Google Glass. However, in this particular test case, this situation was anticipated, as most users already knew the location.

For the past 6 years, since the announcement of Google Glass in 2012 and the subsequent ending of the Explorer beta program three years later, there has not been an HMD that received nearly the same attention from the media. Research is still being poured into these devices, yet they are still too bulky, too new-edgy, too ”weird”, and consumers are not prepared to walk around wearing smart glasses on their heads in their everyday lives [36]. Many of the brands that sell HMDs market-orient their products to specific business areas, namely manufacturing, logistics, or healthcare, even Google itself with the Glass Enterprise Edition launched in 2017 [37, 38].

In the tourism sector, no significant solution emerged in the referred time interval, which supports the results of this dissertation, that the technology is not yet in a state to be used by the general public. Its limitations far surpass its possibilities, and the price of the devices is another hindering factor. To invest in, for example, 10 of these devices to try a new tourism product and then see the experience fail may not be an option for smaller businesses.

For all these motives, despite the perceived potential of conjugating tourism and smart glasses, the early stage of development that these devices are still in does not allow that potential to be explored to the fullest. Even considering newer and more advanced devices, the issues with the design and size of the devices remain.

The current version of the application should have a more robust algorithm to deal with the location fluctuations derived from the errors of the device’s GPS, which would improve navigation and the AR feature. Besides, further tests with a larger group should be made, and the received feedback built upon.

The BO and the back end services could also be updated with this specific use case in mind, with features that more powerful uses of AR on an HMD. With an alternative device and a BO that is oriented to the product, the application should be modified to include map navigation, improve the messaging feature, and have a stronger gamification component.

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