

UNCLASSIFIED



Australian Government

Department of Defence
Science and Technology

Summer Vacation Placement LD04: Investigating the Utility of Augmented Reality for Land Logistics

Matthew Howe, Chelsea Fortuna and Guy Edward Gallasch

Land Division
Defence Science and Technology Group

DST-Group-GD-0964

ABSTRACT

Augmented Reality (AR) is a powerful platform that combines virtual objects and information with real time surroundings. Even though its underlying concepts may resemble virtual reality, AR devices have the potential for mixed reality, where virtual objects can interact with real surroundings. The Epson Moverio BT-200 is digital eyewear capable of producing AR. Its dual screen glasses were cutting edge at their time of release and provide an AR experience using their many sensors. Our study explored the intricacies of working with AR using the Epson Moverio BT-200. The software and hardware capabilities of these glasses were explored and then illustrated through the design and implementation of a number of proof-of-concept and prototype AR applications. These applications were tested and evaluated to scope the possible uses of AR technology in support of our research into Land Logistics and in support of Land Logistics more generally.

RELEASE LIMITATION

Approved for public release.

UNCLASSIFIED

UNCLASSIFIED

Produced by

*Land Division
Defence Science and Technology Group
PO Box 1500
Edinburgh SA 5111*

Telephone: 1300 333 362

*© Commonwealth of Australia 2017
June 2017
AR-016-891*

APPROVED FOR PUBLIC RELEASE

UNCLASSIFIED

UNCLASSIFIED

Summer Vacation Placement LD04: Investigating the Utility of Augmented Reality for Land Logistics

Executive Summary

This report documents the outcomes of an investigation into the utility of Augmented Reality (AR) for Land Logistics and Combat Service support, under Defence Science and Technology Group's 2016/17 Summer Vacation Placement program. The investigation was carried out by two students, Chelsea Fortuna (on a 6 week placement) and Matthew Howe (on a 12 week placement).

AR has been an emerging technology for a number of years and rapid development in hardware and software surrounding this technology now mean that potential applications are being developed within Defence. This report documents the exploration of the use of the Epson Moverio BT-200 AR glasses in a Land Logistics setting and beyond.

Through the course of this investigation a number of applications of AR were conceived, built and/or tested. These applications included an inventory management app, a 'MedicAssist' app, a 3D visualisation tool, and a mechanic tutorial app. Other applications that were not developed or tested in full include terrain visualisation/ simulation, route tracking/optimisation, tele-assistance/tele-operation, invisible armour, and a war game/simulator for training purposes. These ideas encompass some of what Defence could utilise this technology for in the future.

Through this investigation it was found that often the Epson Moverio BT-200 AR glasses were insufficient for visualising complex 3D scenes; however, they can be used for applications where hands-free information, and simple animations/images and videos need to be presented to the wearer. Other AR hardware such as the Microsoft HoloLens and Google Glass should be explored for more demanding applications although these both have their pros and cons which need to be considered before purchasing and deploying.

UNCLASSIFIED

UNCLASSIFIED

This page is intentionally blank.

UNCLASSIFIED

Contents

1. INTRODUCTION.....	1
1.1 Augmented Reality Definitions.....	1
1.2 Epson Moverio BT-200.....	2
2. BACKGROUND RESEARCH	3
2.1 The Device.....	3
2.1.1 Sensors	3
2.1.2 Camera	3
2.1.3 Memory.....	4
2.1.4 Networking	4
2.1.5 Battery Life	4
2.1.6 3D Mode.....	4
2.1.7 Virtual Screen.....	4
2.1.8 Accessories	4
2.2 Augmented Reality Application Development	5
2.2.1 Platforms.....	5
2.2.2 Setting up the BT-200.....	5
2.2.3 Adapting Applications for the BT-200.....	5
3. APPLICATION IDEAS AND EVALUATION	6
3.1 Ideas for Application Development.....	6
3.1.1 Computer Aided Design Visualisation	6
3.1.2 Inventory Management	7
3.1.3 Virtual Tutorials using Graphical Overlay	7
3.1.4 Route Tracking and Recording.....	8
3.1.5 Tele-Assistance.....	8
3.1.6 Base Deployment, Planning and Training	8
3.1.7 Simulation Visualisation.....	8
3.1.8 Invisible Armour	9
3.2 Evaluation of Ideas	9
3.2.1 CAD Visualisation.....	9
3.2.2 Inventory Management	9
3.2.3 Virtual Tutorials.....	10
3.2.4 Route Tracking and Recording.....	10
3.2.5 Tele-Assistance.....	10
3.2.6 Base Deployment Visualisation.....	10
3.2.7 Simulation Visualisation.....	11
3.2.8 Invisible Armour	11
3.3 Observations	11

4. APPLICATION IMPLEMENTATION.....	13
4.1 Inventory Management	13
4.2 MedicAssist App.....	14
4.3 CAD Visualisation App.....	15
4.4 Mechanic Tutorial App.....	17
5. REFLECTION	20
5.1 Applications.....	20
5.1.1 Stock Picking App	20
5.1.2 MedicAssist App	20
5.1.3 CAD Visualisation App.....	21
5.1.4 Mechanic Tutorial App.....	21
5.2 Future Work	21
5.2.1 Physiological Testing	21
5.2.2 Polished App Implementation	21
6. CONCLUSION.....	22
ACKNOWLEDGEMENTS	22
REFERENCES	23
APPENDIX A HELP AND RESOURCES.....	24
A.1 Websites	25
A.2 Common Issues Whilst Creating Apps on Unity3D	25
A.3 Common Issues with Built App.....	26
APPENDIX B TIMELINE.....	28

Glossary

2D	Two Dimensional
3D	Three Dimensional
API	Application Programming Interface
AR	Augmented Reality
CAD	Computer Aided Design
DST Group	Defence Science and Technology Group
GB	Gigabyte
GPS	Global Positioning System
GUI	Graphical User Interface
JDK	Java Development Kit
LD	Land Division
MP	Megapixel
SDHC	Secure Digital High Capacity
SDK	Software Development Kit
SVP	Summer Vacation Placement
USB	Universal Serial Bus
VR	Virtual Reality

This page is intentionally blank.

1. Introduction

Augmented Reality (AR) is a technology that has the potential to transform the way many activities are carried out in Defence. A Summer Vacation Placement (SVP) project was established by the Land Logistics group to investigate the utility of AR technologies for Land Logistics and Combat Service Support (CSS) activities. The investigation was conducted by two Summer Vacation Placement students, Chelsea Fortuna (on a 6 week placement) and Matthew Howe (on a 12 week placement).

1.1 Aims and Objectives

Our initial interest in AR was twofold: as a technology in its own right to assist with logistics, and for its potential utility to increase engagement with stakeholders through more effective communication of concepts and ideas. From this, the SVP project arose as a means to begin the exploration of AR for these two purposes. The specific aim of the SVP project was to investigate the utility of a particular manifestation of AR, namely the Epson Moverio BT-200 AR glasses, and to use the insights gained to draw more general conclusions around the utility of AR for these two purposes. The investigation included gaining an understanding of the technical capabilities, affordances and constraints of these AR glasses, developing ideas for their application to logistics and CSS activities, and building proof-of-concept and prototype software applications for the glasses for evaluation.

1.2 Augmented Reality Definitions

We begin with some definitions to provide context. In this report, we have provided a breakdown of definitions along the progression from ‘actual’ reality through to virtual reality, based on the reality-virtuality continuum given in [1].

- **Actual Reality:** Real environments—what we see and experience with our eyes every day, without alteration or augmentation.
- **Mixed Reality:** The combination of real and virtual worlds. This may or may not include some degree of interaction between the real and virtual components. The superposition of textual information (contextual or otherwise) overlaid on a real environment is an example of mixed reality with little or no interactivity between the real and virtual components. A virtual ball rolling off the table onto the ground is an example of interaction between the virtual component (ball) and real components (table and ground). There are two main subcategories of mixed reality:
 - **Augmented Reality:** The incorporation virtual objects and information within a real environment.
 - **Augmented Virtuality:** The incorporation of elements of a real environment within a virtual environment.

- **Virtual Reality (VR):** A completely synthetic environment within which the user is totally immersed and able to interact.

1.3 Epson Moverio BT-200

The Epson Moverio BT-200, pictured in Figure 1, was released in 2014 and is an Android digital eyewear device. The BT-200 glasses comprise a wearable headset physically tethered to a hand-controller unit, as pictured. Full specifications can be found at [2].



Figure 1 Epson Moverio BT-200 glasses (image via [3])

2. Background Research

At the start of the placement the team had a general awareness of AR but limited knowledge of the BT-200 glasses. A summary of research on both the device itself and on AR application ('app') development is given below.

2.1 The Device

As mentioned above, the BT-200 glasses have a range of sensors and functionalities. The following section details and evaluates each of these capabilities individually. Technical details can be found at [2].

2.1.1 Sensors

The BT-200 glasses are equipped with a Global Positioning System (GPS) receiver in the headset and a compass, accelerometer and gyroscope in both the headset and controller. The quality and accuracy of each of these sensors is comparable to those on a modern smart phone. The data from these sensors can be accessed by an application in the same way as on any Android device, making it a suitable platform for application development. Some difficulty was encountered when trying to access the sensors in the hand controller unit instead of those in the headset. This may be because the presence of multiple accelerometers and gyroscopes is something not usually found in common Android devices such as smart phones and tablets, and hence software development packages for Android may not handle this well.

2.1.2 Camera

There is a 0.3 Megapixel camera mounted on the bottom right of the headset (from the perspective of the wearer). This is a reasonably low resolution relative to other smart devices manufactured at around the same time e.g. the iPhone 6 with an 8 Megapixel rear camera [4]. We speculate that a lower resolution camera may have been used to reduce the price of the product for consumers or to reduce the size of the headset. Regardless, it has been observed that the camera in the headset takes longer to recognise targets/markers (for localisation) than a Samsung tablet of similar age, a more modern Samsung phone or a Microsoft Surface Pro 3. Its delay in recognising objects may not be solely due to the reduced resolution, but also the following factors:

- The device has less processing power than e.g. the Samsung tablet or Surface Pro 3, and so may take longer to process images
- The low resolution of the camera may result in increased human error, as our experience was that combination of the off-centre location of the camera and low-resolution images sometimes made it difficult to tell when the target was properly within the camera's field of view

2.1.3 Memory

In terms of internal memory, the hand controller unit has 1 gigabyte (GB) of working memory and 8 GB of internal storage. The controller also allows up to 32 GB of external storage through a micro SDHC card slot. The networking capabilities discussed later also provide the opportunity for off-board to on-board transfer of large data from external sources such as online databases.

2.1.4 Networking

The device has wi-fi and Bluetooth capabilities (although not Bluetooth Low Energy). It is said to be compatible with Miracast [5] to provide screen mirroring, but we were unable to get this working without proprietary Epson peripherals. We also found that the GPS sensor wouldn't work without wi-fi turned on, but we have not confirmed the reason, nor whether this is an intentional feature of the BT-200.

2.1.5 Battery Life

The battery life is approximately 6 hours for general use. We have observed that displaying 3D images and extensive network communication (e.g. wi-fi) will drain the battery significantly more quickly.

2.1.6 3D Mode

The device has 2D and 3D capabilities. It supports a side-by-side 3D format and for best performance a calibration profile should be made for each wearer. A simple way to do this is to download the Calibration App by Vuforia from the Vuforia website [6].

2.1.7 Virtual Screen

The angle of view is 23 degrees, meaning a 40" screen can be projected at a distance of 2.5 metres. It is large enough for viewing images and basic information but is not suitable for immersive experiences or for displaying fine details (e.g. paragraphs of text). This limitation is not unique to the BT-200, and although AR glasses that can achieve greater fields of view are beginning to be released, none can claim to be fully immersive.

2.1.8 Accessories

Tinted inserts are supplied for outside use or can be used to block out the user's surroundings. For a more realistic augmented reality effect, it is recommended that sunglasses are not worn. Ear hooks are included as well as flexible nose pads to secure the headset. A lens holder is included for users that require regular prescription lenses, such that prescription lenses can be inserted directly into the BT-200 glasses. The device does not have an internal speaker, although audio can be played through an audio jack on the device. Earphones are supplied which also include a microphone, which may be useful for speech recognition in hands-free applications.

2.2 Augmented Reality Application Development

Following an investigation of the features of the BT-200 glasses, we explored the broad area of application development and then focussed more specifically on AR applications for the BT-200. This was a relatively new field for the Land Logistics group at DST Group, where there was little prior knowledge or development on the topic. Thus, research in the areas of software development platforms, device set up and application adaptation for the BT-200 was undertaken. 0 contains some of the resources we found useful and documents our troubleshooting of the issues we encountered.

2.2.1 Platforms

Unity3D [7] and Unreal Engine [8] were the most prevalent application development platforms on the web, both with the ability to incorporate augmented reality plugins. Unity3D is a high level game engine that specialises in computer graphics. It has useful plugins and extensive resources online. Unity3D also included a very easy to use Vuforia Augmented Reality plugin. Vuforia is a company that has produced a Unity library (also known as a 'prefab') for the BT-200 glasses, which is able to be imported into a project and called upon to provide functionality. This made Unity3D the favourable choice for beginner application development for the BT-200 glasses. In addition to this, there was an Epson Moverio plugin that included Moverio Camera Rig and Moverio Controller prefabs for use in Epson Moverio apps.

Unity3D allows the user to create generic applications and then compile them for the required platform, whether it be Windows, iOS or Android. It has a refined 'drag-and-drop' style user interface, but when it comes to detailed coding, Unity3D will redirect the user to Microsoft Visual Studio (if it is installed). In this project, code was written in C# (C sharp) as this is the preferred application development language for Unity3D. In addition to installing Unity3D and Microsoft Visual Studio, an Android Software Development Kit (SDK) and a Java Development Kit (JDK) were required to be installed and referenced when building a Unity3D project.

2.2.2 Setting up the BT-200

To allow applications to be installed directly onto the device from Unity through a USB port, the device had to be set to 'developer mode' with USB debugging enabled.

2.2.3 Adapting Applications for the BT-200

The majority of the application development process for the BT-200 glasses was the same as that for any other Android device. However, care was taken when displaying information on the screen as it has a substantially different aspect ratio to most Android devices. Essentially, the screen is split vertically down the middle, with half of the screen displayed to each eye. Additionally, when using Vuforia, an app license key specific for digital eyewear had to be obtained by signing up to using Vuforia as a developer.

3. Application Ideas and Evaluation

Following the investigation of BT-200 capabilities and software development platforms, a set of desired functions/capabilities for the BT-200 glasses was generated. The idea was that these will provide elements of underlying functionality for incorporation into AR applications. The capabilities were:

1. Bidirectional transfer of data between off-board and on-board storage (via wi-fi and Bluetooth capabilities)
2. Displaying text data:
 - a. Static text
 - b. Dynamically changing text (from internal or external sources)
3. Display of 3D objects
4. Recognising “input” of various forms:
 - a. Text
 - b. Images
 - c. Gestures

Following this, several possible application ideas were discussed that embody some of these capabilities, and are described below. These applications were designed to explore potential use cases for AR in Land Logistics.

3.1 Ideas for Application Development

Most of the ideas developed during this project revolve around the concept of an application recognising an image, object, gesture or text in its surroundings and then displaying contextual text, images or objects relevant to that particular cue. In AR such cues are called ‘targets’. A target forms the basis for interactive AR as it gives the application a real world reference point, which is especially important when using a device that has a single camera (like the BT-200) and hence cannot accurately capture a sense of depth in an environment. (Other products on the market can achieve this through the use of multiple cameras, such as the Microsoft HoloLens.) The following application ideas were designed with this limitation in mind. The BT-200 is able to take the input of the single camera and (attempt to) track the location of objects by tracking targets.

3.1.1 Computer Aided Design Visualisation

The idea of this application is that users could upload Computer Aided Design (CAD) sketches to the BT-200 glasses prior to manufacture, to allow their clients to better visualise new products before production. 3D visualisation allows the wearer to gain a fuller appreciation of how the product will look in real life and a sense of the scale of the whole part or assembly, and to interact with the object more intuitively than can be achieved

through static 2D drawings. Additionally, different functionalities of the object can be demonstrated through animation in the visualisation (e.g. a mechanical assembly).

As well as describing concepts to stakeholders, this same principle could be used to teach people how to perform certain tasks without physical objects being used, so this has significant potential utility in the training of equipment operators and maintainers. For example, when training a maintainer to service a vehicle, all the steps could be performed on a virtual vehicle, without a physical vehicle being present. We explore this further in a separate idea on virtual tutorials later.

3.1.2 Inventory Management

The next idea was an application to assist with inventory management. The glasses could recognise an item and display contextualised information and prompts to the user based on the item recognised. For instance, in a stock room setting, the user may look at a product and retrieve information such as safety data sheets, perform actions such as stocktaking, or record the location of the item so that it can be located again at a later time. Another example of this concept could be in a medical scenario, where staff could look at a drug before administering it to a patient in order to log the usage of that drug. This may make it easier to keep track of inventory and potentially assist with accurate reordering. The hands-free aspect of AR glasses (vs. augmented reality delivered via smartphone or tablet) makes this particularly attractive, as most medical staff require both hands to carry out their work.

The function of providing contextualised display (and recording) of drug information at the time and place of relevance is but one possible use in this context. Often time is a critical element in the survival and effective care of patients. The current system of bells, rolling text displays in hallways and announcements via overhead speakers that are used to get nurses attention immediately may not be the most efficient method of delivering the information needed. AR glasses offer an alternative for the delivery of contextualised, individualised information to individual medical personnel, rather than being announced to everyone in the building.

3.1.3 Virtual Tutorials using Graphical Overlay

The third idea was using AR to assist with repair, diagnostics and assembly tasks, so that technical tasks can be performed by untrained personnel. For instance, the driver of a car that is experiencing engine problems could put the glasses on and look at the engine bay. The glasses could then overlay information onto the car about specific components the driver should check, or things they should do. The graphical overlay could include arrows and circles around parts so that even someone with no previous experience is able to, for example, conduct a vehicle service to an adequate standard (given they have the appropriate tools to hand). In this case, as with the previous one, having a hands-free solution like the BT-200 is particularly beneficial.

This type of application has relevance to Land Logistics in the maintenance area, both for training maintainers, but also for providing interactive, hands-free maintenance manuals.

Such manuals could also be used in tele-maintenance, to assist non-maintainers to perform critical tasks to repair their vehicles if they break down while on a mission, with specialists providing advice and assistance remotely.

3.1.4 Route Tracking and Recording

From the authors' previous experiences a particular use for AR could be in driver training. For example, a team of analysts could investigate the optimal path for a racing car to take to maximise speed and win a race. The driver of the car could, through AR glasses, have this optimal path projected onto the track, with other information such as recommended speed, brake timing, and apex location.

This idea would work in a similar way to existing GPS navigation style applications. However, it has the advantage of being able to project the recommended route onto the ground in front of the user, which may be easier to follow than a non-head-mounted solution. A particular application may be for Army combat vehicles going through rough terrain, or resupply convoys traversing difficult or complex road networks (e.g. contested, congested urban environments). The driver could wear the glasses and steer the vehicle down the path of minimal disturbance/least resistance by following a sequence of virtual waypoints, either pre-defined or recorded by previous exploratory vehicles that traversed the same terrain/road network.

3.1.5 Tele-Assistance

In most of the applications suggested within this report, a need to speak to a professional may arise. It may be possible to speak with people remotely, and for them to annotate the world around you. For example, it may be that a remote expert can draw an arrow or a circle to point out the object you need to look at or inspect, as a way of augmenting verbal instructions. This has application in both tele-maintenance and tele-medicine, where professionals may be able to provide assistance to deployed forces without having to be physically deployed themselves.

3.1.6 Base Deployment, Planning and Training

This idea was about providing the ability to take terrain data, such as topographical data, and show this to a user. This idea is more of an enabling application for other end products than an end product in itself, but the development of this opens up possibilities such as higher-fidelity battle simulations or the ability to plan the layout of a deployed base in a particular location before physically citing it.

3.1.7 Simulation Visualisation

After attending the 2017 DST Group Student Conference it became apparent that the integration of AR into simulation tools for the visualisation of results would offer a significant benefit, both internally within DST Group and in the Australian Defence Force more generally. This would involve the adaptation of current simulation software to

interact with AR glasses. The BT-200 glasses may be suitable for visualising the results of simulation tools.

3.1.8 Invisible Armour

Similar to the use of AR in F-35 helmets, where the pilot is able to see through the cockpit and detect surrounding targets, this could also be applied to vehicles which currently have very limited vision such as tanks. This would involve the implementation of external cameras on the vehicles.

3.2 Evaluation of Ideas

In this section the strengths and weaknesses of the above ideas are evaluated in terms of their potential suitability for implementation on the BT-200 glasses. In some cases this involved the development of rudimentary proof-of-concept applications, some of which were subsequently further developed (see Section 0). Some suggestions for improving the application ideas in the future are given.

3.2.1 CAD Visualisation

This application was built and tested on the BT-200 glasses. Navigation throughout the application worked well, such as scene changes, user interface buttons and check boxes. Visualising objects that remain static within the field of view of the user also worked: the object was clearly visible, it was obviously 3D, and the movement of objects within the AR display had little lag. However, navigation around the object (i.e. the user physically moving around the virtual object) did not function well due to poor target tracking on the part of the BT-200. We suspect this is related to the low resolution of the camera (as noted in Section 2.1.2). When visualising an object using a target as the detection point, the user would often experience lag – the 3D object would appear to move with the user and then jump back to its intended location above the target. The application also had a tendency to crash completely when visualising complex objects. This application also tested some animation of objects, but these also returned poor results in terms of lag and stability of the application for complex objects.

3.2.2 Inventory Management

This application was attempted for the BT-200 glasses to aid in stock location by directing a user towards an indoor location. The use of the built in sensors was implemented as a way to track location, direction, and distance from the reference point of the glasses. Sensors tested included the compass, accelerometer, gyroscope and GPS. Although some of the sensors did function in an appropriate way, other sensors such as the GPS were irregular in the indoor laboratory environment in which this project took place. (Note that we did not attempt to implement GPS-independent inertial navigation due to time constraints.) This made it difficult to represent indoor location information in an organised way that would provide a benefit to the user. The sensor functionality limitations are likely to be localised to using these particular AR glasses and to the particular test

environment (limited visibility of the sky and hence limited GPS signals). Other hardware solutions and/or operation in other environments may prove more successful.

3.2.3 Virtual Tutorials

This application was built and tested for the BT-200 glasses using the specific example of vehicle servicing. It implemented one task (oil change). This application worked well in terms of navigation through the application but was not 'hands-free' as the hand controller unit for the glasses was needed to navigate through the application. In future, navigation could be by voice command, removing this limitation. We intended the application to feature a demonstration function which would allow the user to see the steps being performed on a 3D model. However, the application crashed each time the model was loaded. This may be due to the amount of computer memory needed to store the complex engine assembly model. Besides this issue, this application has the potential to be developed further and implemented more fully.

3.2.4 Route Tracking and Recording

This application was not built or tested, however aspects supporting its implementation were. This application may work well if implemented in a well thought out manner. The path information does not necessarily need to be displayed as a graphic overlay, as it could simply have a 2D direction and pointer visualisation that would work on 2D AR hardware such as Google Glass. The application could also be implemented in 3D AR hardware where the path is highlighted in front of the user. Depending on the accuracy required, one potential issue with an application of this nature is the accuracy of civilian GPS positioning for reproduction of a route. It is likely that military-grade global positioning or other forms of localisation (such as inertial navigation systems or optical tracking) would be required to attain the desired level of accuracy. It is known that even advanced AR devices such as HoloLens, that do utilise multiple mechanisms for localisation, struggle to maintain coherent positioning when used in outside locations. Hence, this application may have to wait until more capable AR hardware is available.

3.2.5 Tele-Assistance

This application was not built or tested, nor were aspects supporting its implementation. However, evidence in the open literature¹ suggest that applications such as this are eminently possible with current AR hardware such as Google Glass, HoloLens and Meta 2, and could be tailored to suit a specific application (e.g. tele-medicine or tele maintenance).

3.2.6 Base Deployment Visualisation

This application was partially built and tested on the BT-200. The application was a simple proof-of-concept for this particular AR hardware. A similar application was later seen during a visit to Saab Australia, where they demonstrated a 3D map of an island, with

¹ e.g. <https://www.theguardian.com/business/2016/sep/19/hololens-the-virtual-reality-headset-for-elevator-repair>

planes, ground vehicles, ships and troops deployed in the area in a wargame simulation. This was implemented using Microsoft HoloLens. The demonstration provided confirmation of both the viability and potential utility of a base deployment visualisation application.

3.2.7 Simulation Visualisation

As with the base deployment application, this application was partially built and tested on the BT-200. The use of AR has a lot of potential for the visualisation of simulations. This could include war gaming/training, where the user is able to be trained in an outside environment rather than through a purely synthetic (i.e. VR) means.

3.2.8 Invisible Armour

This application was not built on the BT-200. See-through or invisible armour could be implemented through either virtual or mixed reality, depending on the particular application. One potential problem could be that the processing of large camera feeds may cause the VR/AR device to operate slowly, but could be mitigated by restricting the 'invisible' field of view to a small area similar to the size of a vehicle windscreen, or offloading the heavy processing to computing devices external to the VR/AR device.

3.3 Observations

Most of the above ideas rely on using targets/markers in the real surroundings to provide localisation, as is required for the BT-200 to function in this way. The targets were also used to influence what would be visualised on the screen, through image or text recognition of the targets themselves. It was found that the use of targets, such as image and text, was the most consistent type of target detection when using the glasses. So-called 'marker-less' augmented reality, achieved through geolocation and other forms of localisation, was found to be unreliable with the BT-200 glasses, as it requires position data that is consistent and accurate. Apart from the inaccuracies inherent in civilian GPS (a precision of 5-10 metres) the laboratory environment within which this research took place afforded a limited view of the sky. For a precision application such as stockroom location, geolocation via GPS or equivalent is not sufficient, and would require augmentation with alternative means of precisely determining location. HoloLens, for example, has such capabilities. Exploring the implementation of such capabilities for the BT-200 was beyond the scope of this project.

Furthermore, after some testing it became obvious that the BT-200 glasses struggle to identify targets when they are too far translated from their expected shape or orientation. We believe this is due in large part to the low resolution of the BT-200's camera. This could cause some difficulties for the accurate detection and identification of inventory in inventory management applications (such as drug packaging in the MedicAssist application in 4.2). Another example would be in virtual tutorials, for example, where each engine bay may look slightly different, due to dust and orientation of the view. In order to have the BT-200 recognise different engine bays, specific 3D models would be needed for

each specific model of vehicle. However, a simpler approach could be taken to make a virtual tutorial for one particular type of engine bay. More advanced techniques, such as the application of machine learning to identify multiple types of engine bay (and engine components therein), are beyond the scope of this report.

Locating supplies seems to be one of the most promising ideas for AR, as DHL and Ricoh have already tested this for stock picking applications in their warehouses using Google Glass. This application displays information about where products are located but does not actually guide you to their location. Although simple, this application is useful, and has been proven to increase productivity. Figure 2 shows DHL's application in action, where it is used to help stock pickers load trolleys correctly and more efficiently. Thus it may be better to generate a slightly different application, one that focuses on stock location querying and guidance, rather than purely on stock location.

The CAD Visualisation application is one way of attempting to use AR to increase engagement with stakeholders through more effective communication of concepts and ideas. Using this, researchers can facilitate a greater understanding on the part of the stakeholders of a concept or product. Thus, CAD visualisation appears to be a worthwhile augmented reality tool to develop further.



Figure 2 Augmented Reality Stock Picking Application in use at DHL (image via [9])

4. Application Implementation

After consideration of the project objectives and AR device constraints, the following applications were developed. As the SVP placement was framed as an exploration of technology with no specific application in mind, each application was presented as a proof-of-concept/prototype rather than a fully functional polished application. Each application implemented an idea from Section 3. Due to time restrictions, the decision was made to develop applications that could be used as a starting point for more complex applications. As such, the applications were intended to be relatively open so as to facilitate future work and extension. Potential extensions are discussed in Section 5.

4.1 Inventory Management

The first application that was successfully developed, built and executed was the inventory management app for use in warehouses. Screenshots are shown in Figure 3. This is an app that uses a 2D overlay of information within the field of view. The app can provide warehouse personnel with inventory information immediately about a particular product by recognising a product using the BT-200's camera. Fundamentally, the wearer can scan an item in a stockroom by looking at it with the glasses on, and then the glasses present the wearer with product-relevant information. The application's menu has three options: Properties, Stocklist, and Location. The Properties button displays an identification number of the scanned product and product description to the user for viewing and editing. The Stocklist button is versatile and can be used perform stocktake or add a list of products to an order. The user would simply have to go around looking at the desired products with the glasses on and they would be added to a list for future reference. The final option, Location, allowed the user to record the location of a product in a warehouse using GPS and compass data from the device, or through manually-entered location information. This would be useful when an employee wants to find an item that's been relocated or plan where there is empty space to place a new product.

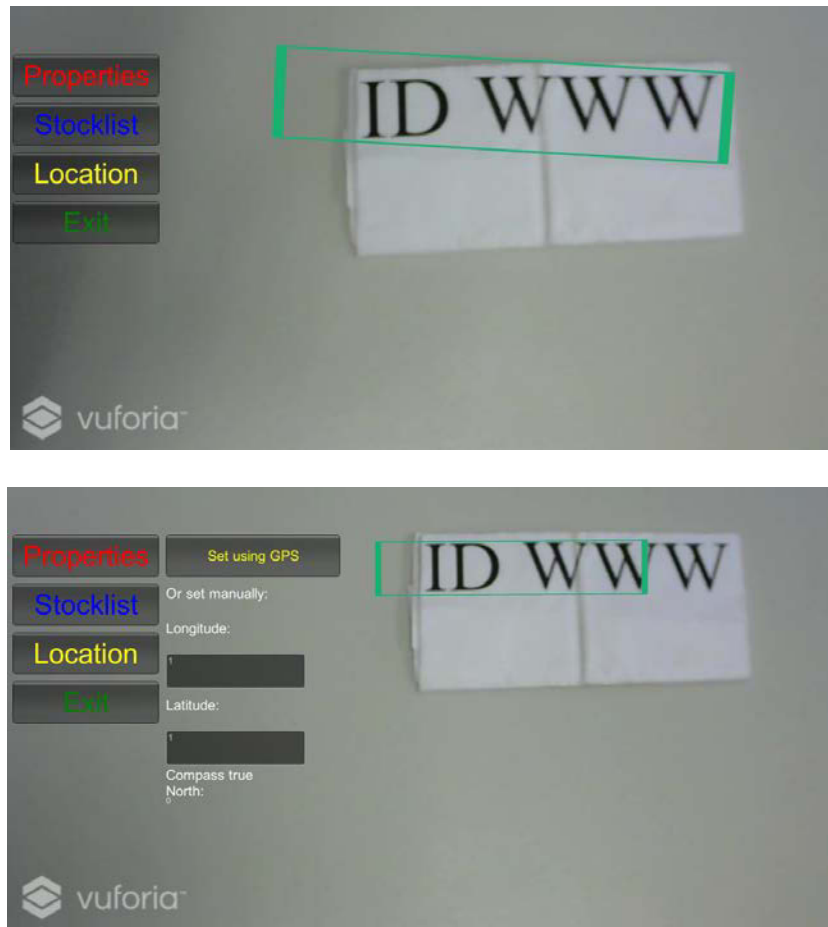


Figure 3 Screenshots of the Inventory Management app recognising text

4.2 MedicAssist App

This application uses the same underlying concept as the previous Inventory Management application of item recognition leading to relevant information display. It is intended to assist medical staff when administering medication in hospitals, and is shown in Figure 4. A doctor, nurse or pharmacist could wear the glasses and look at a product to recognise it. Relevant information about the product is then displayed and the user can then select to know more information or simply continue. This also has application in tele-medicine, where this application could also be implemented with a Skype-like call scenario where a doctor can guide a user through steps, by watching through the camera of the device to see what the user is seeing. Whether or not this is possible with the BT-200 glasses, and if so, how difficult it would be to implement, is beyond the scope of this paper.

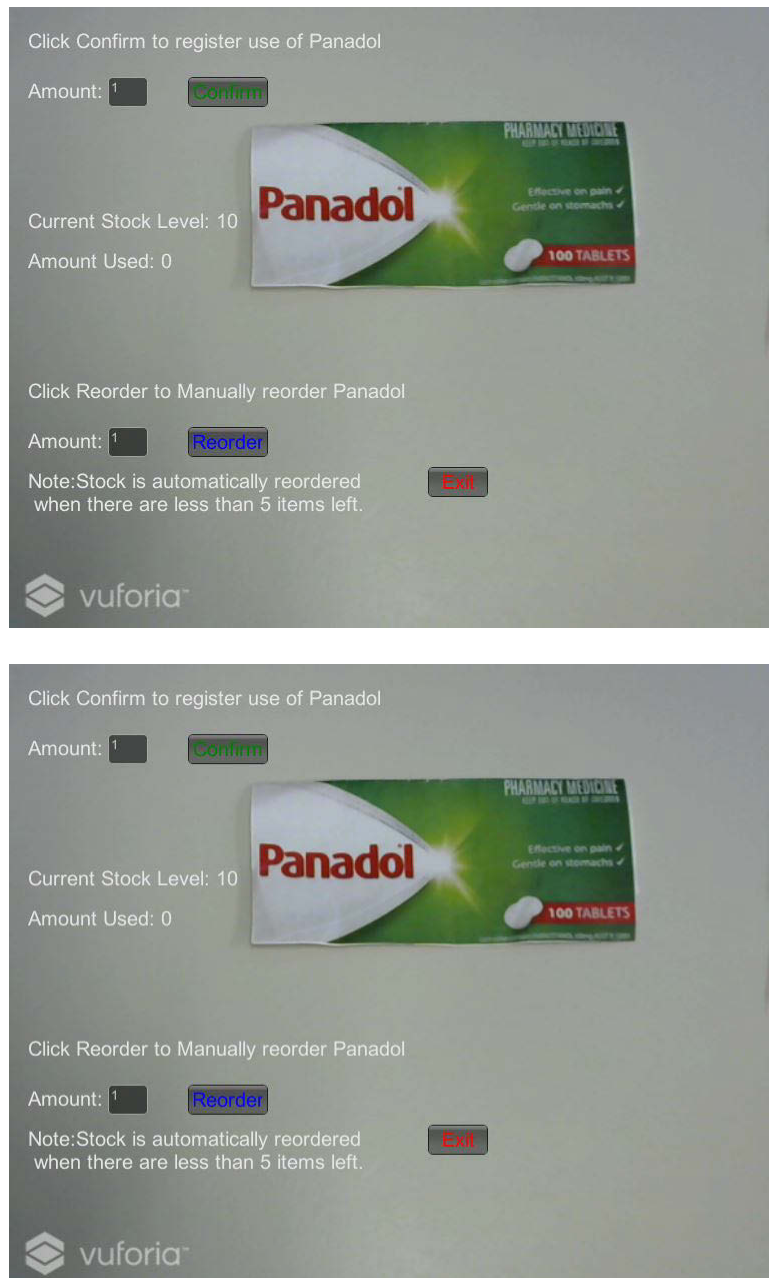


Figure 4 Screenshots from the MedicAssist App

4.3 CAD Visualisation App

This application was a simple proof-of-concept to check the viability of looking at 3D objects through the glasses. Some examples are shown in Figure 5. This application also served as a basis for the base deployment visualisation application (see Figure 6). Although this application works, it did not work as well as expected when adding multiple virtual objects into the scene, as the BT-200 glasses struggled to keep track of

them. There were also difficulties visualising terrain models, not through technological limitations but because we were unable to obtain 3D topographical data in the timeframe required. The graphics processing capabilities of the BT-200 glasses also appear to be substantially limited. Attempts to display complex animations and objects resulted in a jerky, low refresh rate visualisation, and if a quick movement of the user's head occurred the object could 'jolt' or get lost in the surrounding space, and not track correctly against the target.

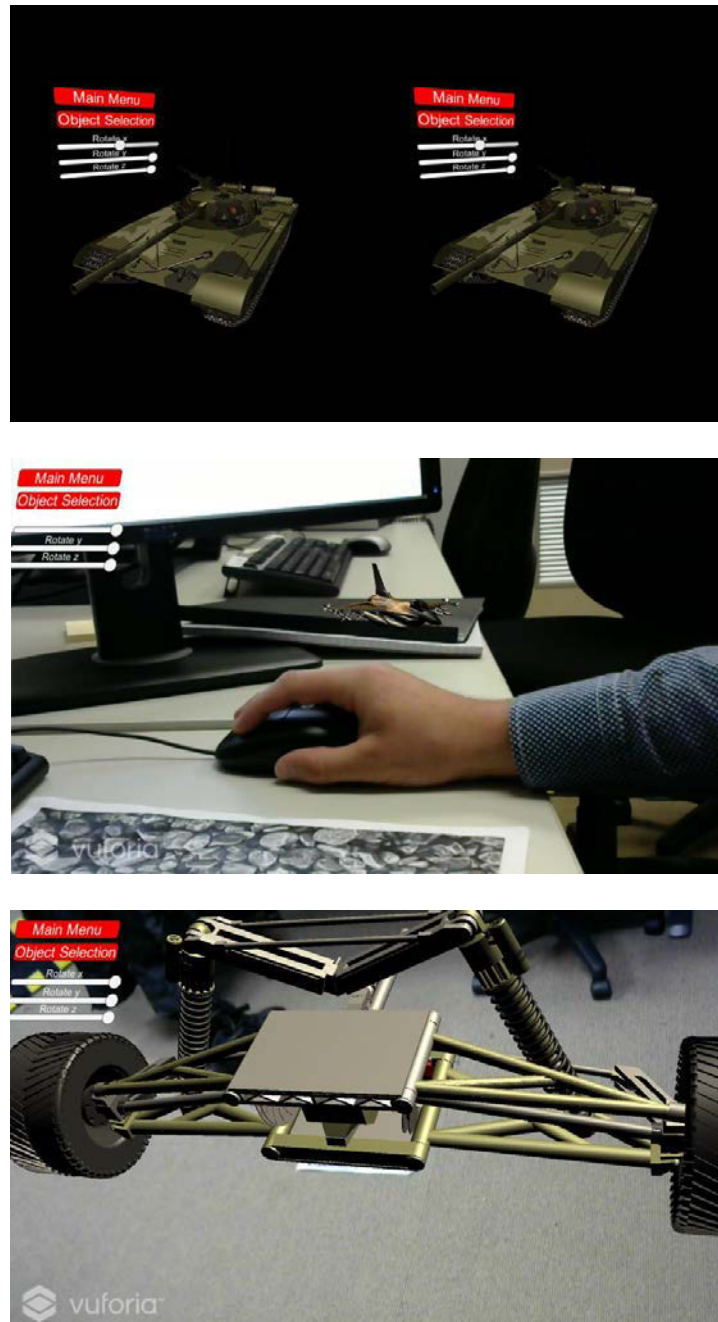


Figure 5 Screenshots of the CAD Visualisation App

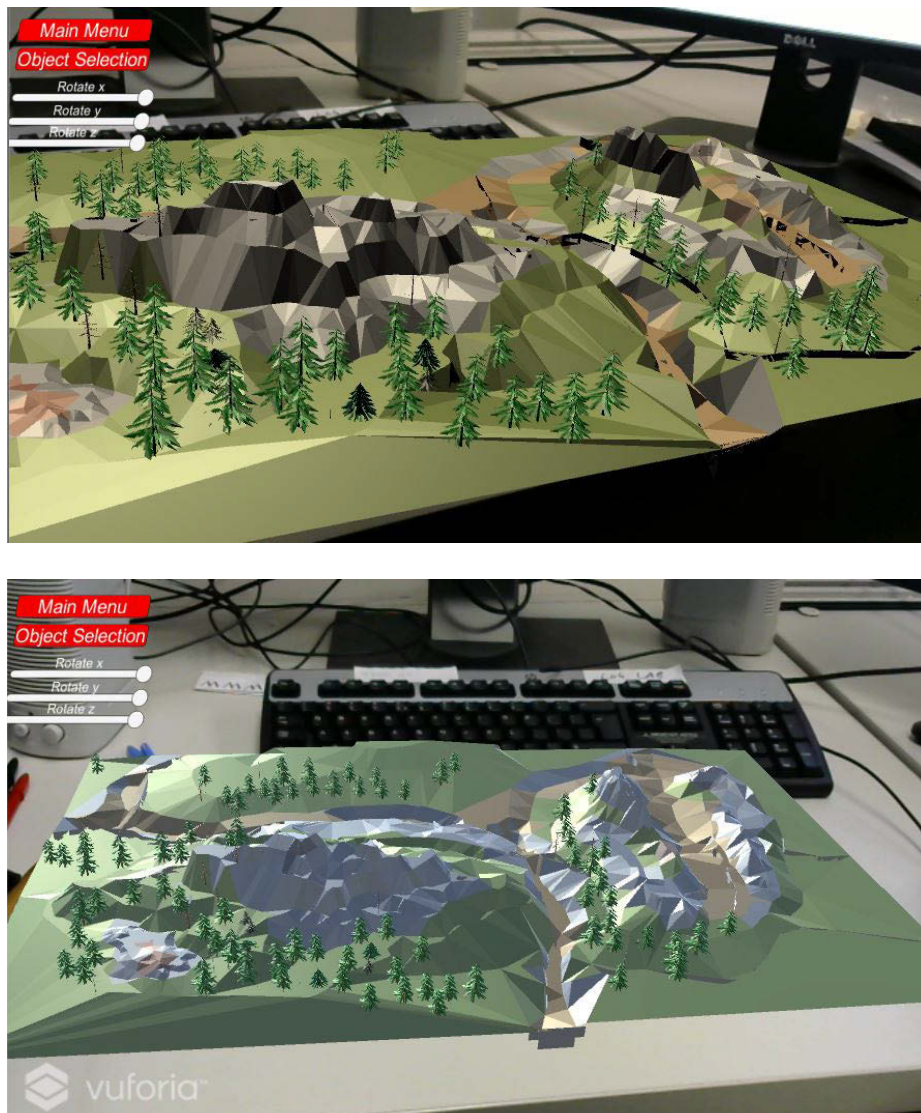


Figure 6 Screenshots of the CAD Visualisation App demonstrating the potential for Base Deployment visualisation applications

4.4 Mechanic Tutorial App

This app builds on the CAD Visualisation app. The app runs through a simple tutorial of performing the removal of an oil filter from an engine, which includes the following four steps with instructions:

1. Materials needed
2. Place oil tray under engine
3. Remove oil sump
4. Remove oil filter.

This app works well, and it is an accurate proof of concept of the application. We attempted to add a feature to steps 2-4 to display an animated demo of the steps being performed. However, the glasses could not keep up when displaying the complex engine assembly and crashed each time this was attempted. This process can work but may require more development time, and/or a different AR device with more computing power. As can be seen in Figure 8, the instructions are placed around the field of view of the user as an attempt to minimise the obstruction of view.

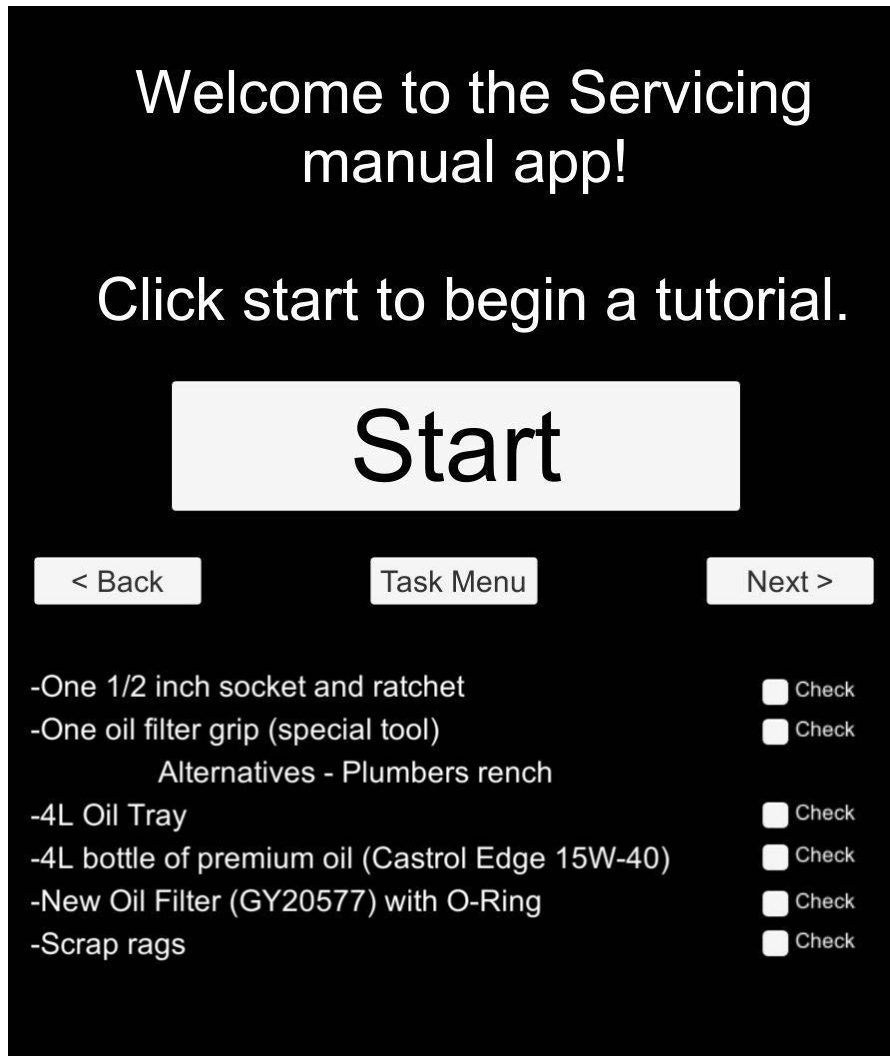


Figure 7 Screenshots from the Mechanic Tutorial App (without the real world backdrop)

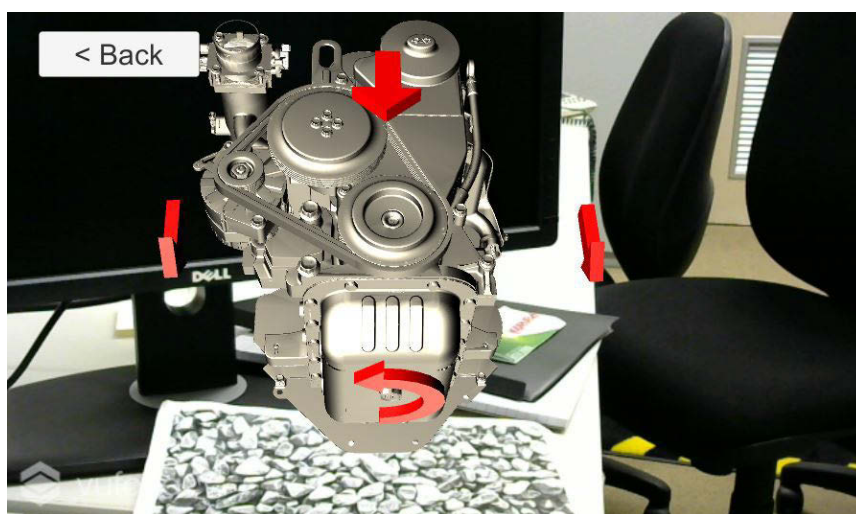
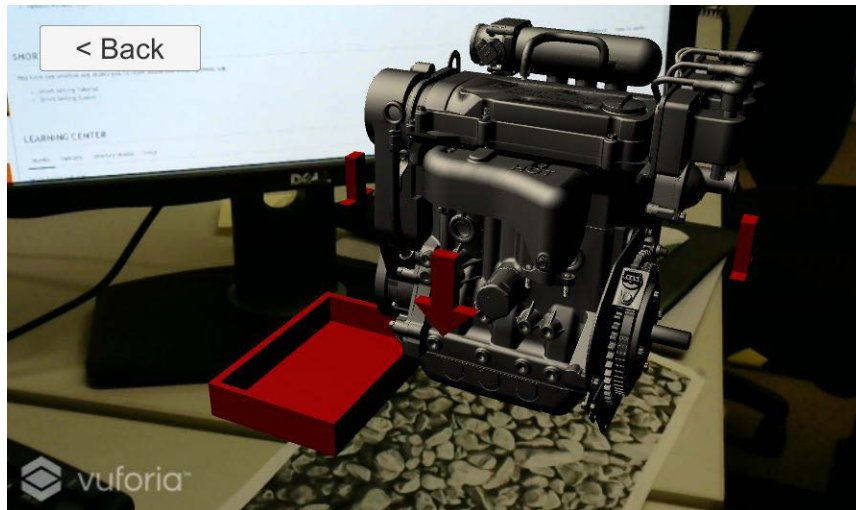
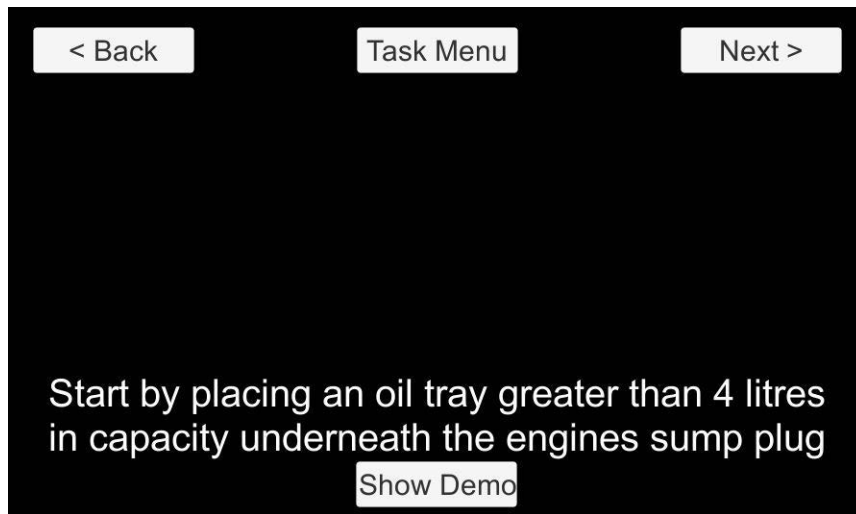


Figure 8 Attempts to incorporate animation within the Mechanic Tutorial App

5. Reflection

The following section provides our reflections on the performance of each application and specifically its limitations, potential improvements and options for future work. In general the applications were fine as proofs-of-concept of the ideas, but would not work well for complex applications. If simple hands-free applications are desired, the BT-200 may be able to provide that capability.

5.1 Applications

5.1.1 Stock Picking App

Currently, this application uses text recognition to identify an ID number that would be assigned to each product. This could be improved to identify a barcode or serial number instead, which may already be present on every product. This would make the application easier to implement as new ID numbers do not have to be assigned to each product, attached and updated in a database. Alternatively, a separate handheld barcode scanner could be integrated with the glasses to provide identification.

It was desired for the application to guide a user through a warehouse and locate stock. With the BT-200 glasses it was not possible to use location data other than the GPS in the time available, however this could be implemented in the future but may not work well due to the particular limitations of the BT-200 glasses (e.g. HoloLens provides much more sophisticated localisation capabilities). GPS can provide approximate position data, however in the application of stock location there was no simple way of attaining the accuracy required. The stock application could still be used to display information and this was achieved as a possible use for the BT-200 glasses. There is also the possibility of using separate sensors to triangulate the position of the user when tagging a location of an item of stock, then using that data to locate it. This however was out of the scope of the project.

5.1.2 MedicAssist App

The MedicAssist application currently has simple functionality. This was a proof of concept built to test algorithms and a method of developing applications. In the future, the following extensions/improvements should be considered: the implementation of an improved user interface; an expanded version targeted at doctors as well as nurses; simple algorithms to learn the usage rates of medicines and to automatically reorder them appropriately; an audio-only version that does not block nurses' vision; improved acquisition and display of patient data; and the use of hand gestures and voice recognition for controlling the app. These are all functionalities which may be useful in this type of application in the future.

5.1.3 CAD Visualisation App

This application would suit AR hardware that is capable of performing faster graphics processing so that models of higher fidelity can be visualised more accurately, and without lag. A simple mechanism for the transfer of CAD models into the application will need to be developed in order to make the application simple to use. There are many ways to improve the user interface which can steer away from using the hand controller unit, like gesture recognition and voice recognition.

5.1.4 Mechanic Tutorial App

This application would suit a HoloLens, where in-depth detail can be shown with 3D models, or simply a Google glass application where only a 2D information overlay is shown with basic instructions and check boxes. This application has been built specifically for the BT-200. By having text away from the centre of the viewing screen, the user is able to look through the glasses easier than if the text covered the screen. The use of the hand controller unit is still required and future work could involve incorporating gesture and voice recognition for hands-free operation. This could be as simple as saying “next” to progress the tutorial to the next step.

5.2 Future Work

5.2.1 Testing of Usability and Efficacy

Within DST Group there has been previous research into the application and efficacy of virtual reality. It may be useful to undertake this kind of testing to estimate the benefits of implementing augmented reality for particular applications by testing the underlying principle of the application. For a 3D visualisation application, this might be creating an application that can simulate an assembly process and then getting participants to perform the assembly, and compare this to the performance of participants that learn the assembly process through a set of written instructions, either hard-copy or on a tablet. This kind of testing should reveal whether or not such an application can readily increase training efficacy and outcomes.

5.2.2 Polished App Implementation

Currently the apps that have been developed are proofs-of-concept and prototypes only, and are not final polished apps. In the future, once specific target applications are determined, targeted development effort can be applied to further developing proofs-of-concept and prototypes into polished apps. This is possible with the BT-200 glasses, but will require resourcing.

6. Conclusion

At the time of their introduction in 2014, the Epson Moverio BT-200 AR glasses presented a reasonable AR package suitable for a range of applications. Even today, we found that users are able to easily see through the glasses, which means they can still be comfortably worn while switched off, as well as while information is being shown. However, three years is a substantial amount of time in terms of technological development, and consequently the glasses are somewhat dated in functional terms, particularly with respect to camera resolution and processing power. The visualisation of dynamic objects attached to targets should be used with caution, as we found that the processing power in the glasses was not sufficient to keep up with target tracking and displaying the 3D objects. This was increasingly our experience as the 3D object models became more complex. For this reason, these glasses may be best suited to static text applications or display/animation of simple 3D objects. Users will also need to be aware that the display does block their primary vision, which will need to be accounted for in the design of any application.

The hardware requirements for augmented reality applications will vary, and there is not one piece of hardware which will perform well in every application. Hence in order to effectively buy hardware for an application, the application will need to be scoped, if not well defined, prior to buying the hardware. Things to consider are processing power, weight, battery life, field of view, software compatibility, and integration with other hardware/software that may be required.

In terms of applications for AR in Land Logistics, beyond its use as simply a stakeholder engagement tool, DST Group should invest in developing AR for simulation, training and maintenance tools, as the three most viable applications relating to logistics. The state of AR hardware is currently sufficient to achieve these simple tasks, however some research needs to go into validating whether or not such technology and applications actually do increase productivity and effectiveness (such research was beyond the scope of this study). To us, this remains the main concern with AR technology: cutting through the hype, can AR be made useful in a practical sense? The DHL case study shows that it has potential.

Acknowledgements

Matthew and Chelsea would like to thank their supervisors, Guy Gallasch and Nick Brealey, for their help and support throughout our summer vacation placement.

References

1. *Mixed Reality - Wikipedia*. (2017), Updated 25 March 2017 [Accessed 27 March 2017]; Available from: https://en.wikipedia.org/wiki/Mixed_reality.
2. *Moverio BT-200 Smart Glasses Specifications - Epson Australia*. [Accessed 27 March 2017]; Available from: http://www.epson.com.au/products/ProjectorAccessories/Moverio_BT-200_Specs.asp.
3. Epson (2015) *Epson Moverio BT-200 Next Generation Smart Glasses Australia*. [Accessed December 2016]; Available from: <http://www.epson.com.au/microsite/moverio-bt-200/>.
4. *Epson Moverio Youtube Channel*. (2016), [Accessed December 2016]; Available from: <https://www.youtube.com/user/MoverioChannel>.
5. Wikipedia (2017) *Miracast*. [Accessed January 2017]; Available from: <https://en.wikipedia.org/wiki/Miracast>.
6. PTC Inc. *Download Tools | Vuforia Developer Portal*. [Accessed 27 March 2017]; Available from: <https://developer.vuforia.com/downloads/tool>.
7. Unity Technologies (2017) *Unity - Game Engine*. [Accessed February 2017]; Available from: <https://unity3d.com/>.
8. Epic Games Inc. (2017) *What is Unreal Engine 4*. [Accessed February 2017]; Available from: <https://www.unrealengine.com/what-is-unreal-engine-4>.
9. DHL successfully tests Augmented Reality application in warehouse. (2014) *Delivered - the Global Logistics Magazine* DHL, 2014 [Last accessed December 2016] Available from: <http://www.delivered.dhl.com/en/articles/2014/12/dhl-successfully-tests-augmented-reality-application-in-warehouse.html>

This page is intentionally blank.

Appendix A Help and Resources

A.1 Websites

The following websites were used throughout the project to assist with application development.

Moverio YouTube channel

- Has useful videos about app development basics specific to BT-200:
- <http://www.youtube.com/moverio>

Vuforia Website

- Support Centre and Forums: <https://developer.vuforia.com/support>
- Manage licenses and Targets:
<https://developer.vuforia.com/targetmanager/licenseManager/licenseListing>

Unity3D website

- Forum and Answers sections: <https://unity3d.com/community>
- Tutorials: <https://unity3d.com/learn/tutorials>

Stack Overflow Website

- Helpful for coding basics (C# and Java are the most common languages used for app development): <http://stackoverflow.com/>

Android Studio website

- Useful for Android specific application functions, contains an in-depth guide to the functions that are built into Android studio. <http://www.androidstudio.com>

Udacity

- Online training platform which offers free tutorials on various technologies and software, explicitly the Android basics courses, this course will teach someone how Android applications work and how to build them. <http://www.udacity.com>

A.2 Common Issues Whilst Creating Apps on Unity3D

The following troubleshooting techniques are intended to assist those new to Unity3D and application development.

Using the console: Use the console to debug your program (the tab next to “Project” at the bottom half of the screen). `Debug.Log(variable OR “line of text to be displayed in console”);` can be placed anywhere in your code to test if certain pieces are working correctly.

GUI Labels/ Text Fields/ Buttons aren’t working/ appearing on screen: Graphical User Interface (GUI) functions must be called from the `OnGui()` function directly or from a method derived from it. `OnGUI()` is called every iteration of the program.

Make sure the rectangle in which you are specifying the text location is within the dimensions of the screen.

GPS doesn’t work: GPS tends not to work in editor even with Unity remote. Try it on the device and make sure location is on and wi-fi is on. If using mock location, turn off wi-fi (use mock location by enabling in developer mode and downloading a mock location app).

A.3 Common Issues with Built App

This section is more directed at the technicalities of getting an application onto an Android device.

Not recognising device/downloading to device: Make sure the device is on and connected to the PC, developer mode is enabled and USB Debugging is on.

Make sure the Application Programming Interface (API) is selected according to the version of Android on the device (see the inspector settings).

How to build an App: Within Unity3D:

- Go to File > Build settings > Switch Platform to Android Device.
- Go to File > Build settings > Add Open Scenes (or at least one scene must be selected).
- Go to File > Build settings > Player Settings > Bundle Identifier must be of form `com.CompanyName.ProductName` and neither your product or company name can have spaces.
- Go to File > Build settings > Build and run. At this point it might ask you to save the build, this must be saved in the Assets folder, make a builds folder inside Assets to save all your builds in.

Downloading but not working: If you are using a Vuforia plugin AR Camera you must enter a license key in the inspector, get this from your Vuforia account on the Vuforia website. Remember there are different license keys for mobile devices (i.e. Samsung Tab) and digital Eyewear (Moverio).

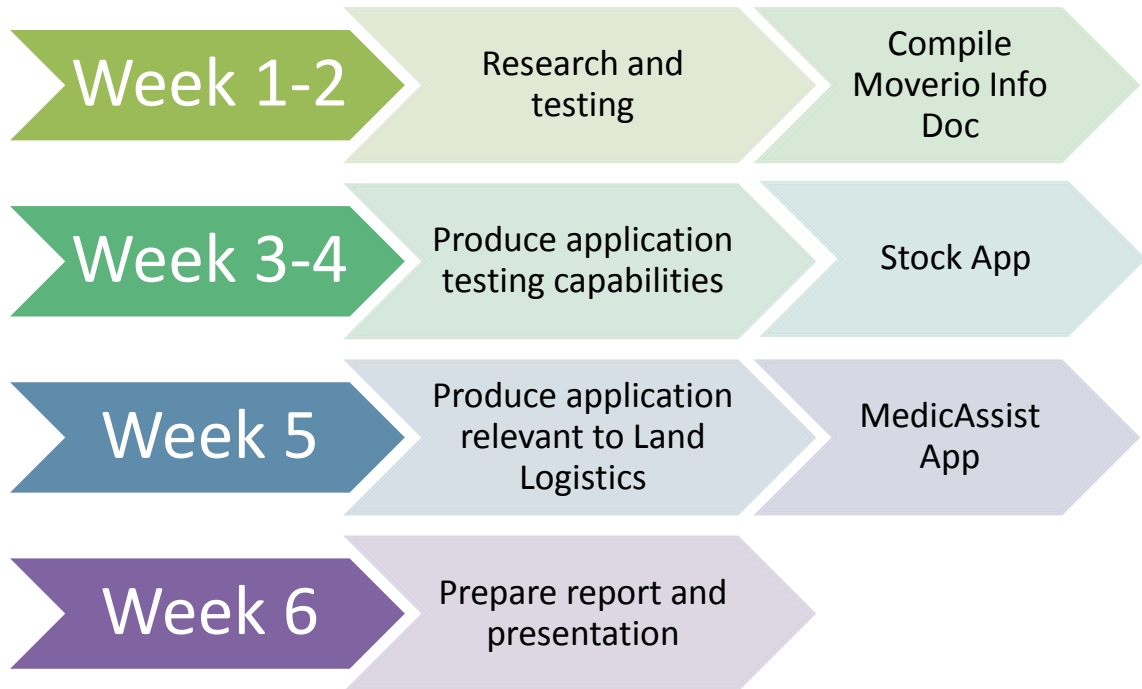
When using AR Camera and Moverio Camera Rig on Moverio, the screen will be black with a vuforia icon in the corner. The app is waiting for a target to be detected which may take a little while. Remember the camera is on your right side.

Playing app on device without doing a full build: Download the Unity remote from the play store and connect the device to the computer and open the app. On the PC navigate to Edit > Project Settings > Editor > Device > Any Android Device. This is helpful as it allows you to utilise the sensors on the device and see how it will appear on screen and in the console without doing a full build.

This page is intentionally blank.

Appendix B Timeline

Chelsea undertook a six week placement which followed the timeline below.



Matthew undertook a 12-week placement with the timeline below.

Week 1	<ul style="list-style-type: none">•Get familiar with hardware•Research software available
Week 2	<ul style="list-style-type: none">•Download required software•Get application on device
Week 3	<ul style="list-style-type: none">•Continue building basic applications•Determine scope of project and set goals
Week 4	<ul style="list-style-type: none">•Begin using built in sensors•Determine usability
Week 5	<ul style="list-style-type: none">•Continue onto more advanced sensors (GPS)•Determine usability
Week 6	<ul style="list-style-type: none">•Begin preparing presentation•Work on 3d visualisation application
Week 7	<ul style="list-style-type: none">•Presentation to STC•Begin working on servicing application
Week 8	<ul style="list-style-type: none">•Begin learning basic Android specific app development•Begin working on Android networking capability
Week 9	<ul style="list-style-type: none">•Practice presentation•Continue with learning Android networking capability
Week 10	<ul style="list-style-type: none">•Conference week•Site visit to SAAB
Week 11	<ul style="list-style-type: none">•Finalising report•Cleaning up computer files ready for handover
Week 12	<ul style="list-style-type: none">•Finalise report•Clean workspace and organise files/documents•Write instructions for running applications•Test applications on all devices.

UNCLASSIFIED

DEFENCE SCIENCE AND TECHNOLOGY GROUP DOCUMENT CONTROL DATA				1. DLM/CAVEAT (OF DOCUMENT)	
2. TITLE Summer Vacation Placement LD04: Investigating the Utility of Augmented Reality for Land Logistics			3. SECURITY CLASSIFICATION (FOR UNCLASSIFIED REPORTS THAT ARE LIMITED RELEASE USE (U/L) NEXT TO DOCUMENT CLASSIFICATION) Document (U) Title (U) Abstract (U)		
4. AUTHOR(S) Matthew Howe, Chelsea Fortuna and Guy Edward Gallasch			5. CORPORATE AUTHOR Defence Science and Technology Group PO Box 1500 Edinburgh SA 5111		
6a. DST GROUP NUMBER DST-Group-GD-0964		6b. AR NUMBER AR-016-891	6c. TYPE OF REPORT General Document	7. DOCUMENT DATE June 2017	
8. OBJECTIVE ID AV14867171	9. TASK NUMBER 07/428	10. TASK SPONSOR N/A	11. MSTC Land Vehicles and Systems		12. STC Land Logistics
13. DOWNGRADING/DELIMITING INSTRUCTIONS			14. RELEASE AUTHORITY Chief, Land Division		
15. SECONDARY RELEASE STATEMENT OF THIS DOCUMENT <i>Approved for public release</i> OVERSEAS ENQUIRIES OUTSIDE STATED LIMITATIONS SHOULD BE REFERRED THROUGH DOCUMENT EXCHANGE, PO BOX 1500, EDINBURGH, SA 5111					
16. DELIBERATE ANNOUNCEMENT No limitations					
17. CITATION IN OTHER DOCUMENTS Yes					
18. RESEARCH LIBRARY THESAURUS Augmented Reality, Head up displays, Logistics, Combat Service Support, Concept Development and Experimentation					
19. ABSTRACT Augmented Reality (AR) is a powerful platform that combines virtual objects and information with real time surroundings. Even though its underlying concepts may resemble virtual reality, AR devices have the potential for mixed reality, where virtual objects can interact with real surroundings. The Epson Moverio BT-200 is digital eyewear capable of producing AR. Its dual screen glasses were cutting edge at their time of release and provide an AR experience using their many sensors. Our study explored the intricacies of working with AR using the Epson Moverio BT-200. The software and hardware capabilities of these glasses were explored and then illustrated through the design and implementation of a number of proof-of-concept and prototype AR applications. These applications were tested and evaluated to scope the possible uses of AR technology in support of our research into Land Logistics and in support of Land Logistics more generally.					

UNCLASSIFIED