A cloud based Edtech framework for augmenting 3D physical objects to assist vocational learning.

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Authorship Statement

This dissertation is based on the results of research carried out by myself, is my own composition, and has not been previously presented for any other certified or uncertified qualification.

The research was carried out under the supervision of Daren Scerri.

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June 7, 2021

Copyright Statement

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Abstract

Technology nowadays is constantly evolving. It is becoming a part of our lives and it is slowly being integrated in every sector such as education, medicine etc. The use of modern technology is becoming essential to educate students. Even though there are numerous studies that highlight the benefits of technology, this still lacks in vocational learning.

The aim of this paper is to introduce the use of Augmented Reality (AR) in a mobile application to aid lecturers to create content for students to deliver a lecture. This study aim to seek the difference between local and foreign AR projects, AR for vocational learning and AR for educational use.

Given the nature of online learning and other emerging trends, this study's goal is to change the traditional way of learning to using an AR mobile application to learn and teach students. This is done by creating 3D models, creating AR content around the model and save on the cloud. This will make the student's and lecturer's life much easier.

This study include a mixed approach which involved both quantitative and qualitative research methods. Quantitative data was collected and analysed using the profiling tools and tests at different angles and distances. It was concluded that users preferred using the AR mobile application than the traditional way of learning. Also having a large or medium size 3D model is better than having a small 3D model for accuracy and detection purposes. Qualitative research was carried out with thirteen participants who took part in an online survey. The online questionnaire was also performed following a pilot-test in a classroom at the MCAST Agribusiness Centre and feedback was gathered after the participants made direct use of the developed AR mobile application. Qualitative data questions were analysed using Google's NLP API and visualisations of results were produced.

This study concluded that the participants chose to use the AR mobile application over the traditional way of learning, the cloud storage that the user can create an individual account and labels can be saved and loaded. The last main result is related to the accuracy and performance of the AR mobile application. It was found that smaller 3D model does not have a better accuracy compared to medium size 3D models. Also, the present time frame is much faster than the render time of the smartphone.

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Chapter 1

Introduction

This study focuses on how lecturers can deliver a lecture using a Multi-User Augmented Reality mobile application that detects a model target which is a 3D life-like model. The intention is that students can use this application as well to study and practice on the 3D life-like model instead of looking at a poster. This study proposes a prototype which can make use of the creation of an easy-to-use tool to create augmented reality content by importing 3D object scan. A multi-user function in a class means that, students can log in simultaneously and view AR content at different angles. Class/group approach can make the use of this framework for the creation of AR without the knowledge of coding by content creators and for educational use. Cloud databases were used to save and load the labels that were created around the 3D model. As a test case the AR mobile application was tested by the institute of Agribusiness, using animal models to detect 3D models and creating AR content around it. However, the AR mobile application can be used on other models such as cars and motors. An analysis of performance on different 3D objects, ambient conditions and accuracy will be conducted.

1.0.1 Motivation and Objectives

Augmented reality is a technology that merges the virtual and real worlds to help users complete their work or deliver a new experience. The smartphone has made it possible to experience AR (Yoo and Lee, 2014). The motivation was that of determining whether an AR mobile application can be used for teaching and learning purpose. This will replace the more traditional ways of leaning such as posters and presentations and will be a dynamic application because it will include scanning of 3D models and Cloud database. It is also a flexible tool that can be used anywhere at any time. Review of AR technologies, platforms and cloud databases on how these can be integrated in such an application. The motivation for this study stemmed from the needs of the MCAST agribusiness institute. The agribusiness institute within MCAST frequently encounters difficulties in teaching and learning which involves real scenarios e.g. large live animals. Due to inaccessible environments and precautions that need to be taken with live animals. To address this problem the institute makes use of 3D models which however lack in themselves the content to be learnt. Augmented reality can address this problem and improve accessibility through the use of mobile applications which accurately display augmented content like model labelling, placing objects, information, audio or video to facilitate learning through these expensive models. However, this study goes beyond the needs of the Agribusiness institute as it proposes a dynamic AR content development system which can be used in other sectors and scenarios. The Agribusiness institute's problem is being used as a test case for a pilot-study to test out the proposed solution.

1.0.2 Purpose of this study

The purpose of this experiment is to test the use of augmented reality to assist in vocational training. This study proposes a prototype which can make use of the creation of an easy-to-use tool to create augmented reality content by importing 3D object scans. The dependent variables of this study are the learning experience from a user's point of view and AR performance in 3D space from a technological perspective. The independent variables will be defined as lightning conditions, camera angle, multi user functionality, label positioning and scaling. Two versions of the prototype will be created with the first one serving as a control variable to assess improvements provided by the second prototype which include multi use functionality, user imported 3D scans instead of hard coded and coded ones and improvement to the tracking capabilities. Given that the aims of this study are to investigate both the user experience and performance of AR, qualitative methods will be used for analysing the user experience while quantitative metrics will be used to analyse the performance.

1.0.3 Hypothesis

Given the above purpose statement, the hypothesis of this study is that through an easy to use dynamic AR modelling and content creation system, more immersive and interactive vocational learning experience can be provided.

1.0.4 Research Questions

Given the above hypothesis the following three research question were formulated.

1. Can Augmented reality truly facilitate teaching and learning that involves real scenarios?
2. How can a cloud storage prototype be developed for multiple users to dynamically scan a 3D object and consequently add AR content around it?
3. How can such a prototype be evaluated in term of accuracy and performance?

1.0.5 Considered Technologies

Platforms that were being considered for this study are Unity, Unity Mars and AR Foundation. These three platforms can deliver an AR mobile application. To access some of the features that Unity Mars has, one has to pay for an annual subscription. Although Unity Mars and AR foundation work together, within Unity can be integrated Vuforia. Vuforia development is where 3D point clouds are stored. Vuforia was considered because 3D models can be created and uploaded as a 3D object and these can be scanned using Vuforia object scanner which is a free application, while Firebase real-time database is free and can be used on all types of platforms. This is being considered because this study required data to be saved online and securely. Also, the application is dynamic so the user can register and have his their own account stored inside Firebase.

1.0.6 Significance of the study

The significance of this study is to propose an application which lecturers can use it while delivering a lecture to students. The students can make the use of this application while the lecturer is explaining and can experiment with the main functionalities like creating labels and positioning them according to the represented organ. Another main functionality is the possibility of detecting multiple 3D life-like models. This functionality makes this study much more significant as it proposes to go beyond many other studies which are restricted to specific objects or a single subject domain, through the development of a highly dynamic and easy to use system. The advantage of the proposed system is its adaptability to any subject domain which involves the teaching and learning about real-life objects.

1.0.7 Research Outline

Following the introduction, a literature review (Chapter 2) is conducted where a background to Augmented Reality is presented. Related foreign and local projects were examined well as AR in education and vocational learning. Some limitations were mentioned followed by some benefits and a discussion about different technologies.

In the methodology (Chapter 3), the tools that were used together with the pipeline of the system are presented. Some pseudo code is also presented with explanation.

In the discussion of results (chapter 4), the data collected from the questionnaires and results from the AR mobile application are discussed while testing the mobile application in the aspects of accuracy and performance on different models.

Conclusions were then drawn whilst bearing in mind the research questions and other studies. The limitations and suggestions for future research are also included.

Chapter 2

Literature Review

This review seeks to explore relevant work within the field of Augmented Reality, and consequently its application to deliver a lecture using a multi-user AR mobile application. Other studies and relevant research papers were consulted. These sources helped the author understand different technologies and, determine knowledge gaps and challenges in the chosen scenario. The first part of this review is a background study of AR and other local and foreign projects, that employ AR as a mobile application whilst the second part focuses on studies about cloud databases, AR frameworks, benefits and challenges within the field. Finally, the application of the above techniques for a multi-user AR mobile application is investigated.

2.1 Background of AR

Augmented Reality (AR) is a popular technology that manages to combine the real world and the virtual world together to create new experiences and environments. AR technology is also possible to experience on smartphones making it available to more users (Yoo and Lee, 2014). The difference between AR and Virtual Reality is that VR creates a whole new detached virtual experience and AR adds a virtual overlay to the physical world space. In VR the user experiencess a whole new world and each person needs their own equipment. However,in AR the user is enhancing the actual environment, whilst multiple people can explore content simultaneously (Mathlin, 2021). As of recent years, mobile devices have been upgraded with the inclusion of new features which can support Mobile Augmented Reality (MAR). MAR is a new experience for users and is being welcomed by many and being spread throughout mobile app markets. MAR is one of the many developments being adapted from classic AR technologies (Zhang et al., 2014).

2.2 Recent Developments in AR

In the past few years, there have been many developments in Augmented Reality. In 2017 Apple's ARKit and Google's ARCore software has standardised their development tools and mobile AR app creation which doubled the number of AR-enabled devices and tripled the active users for 1.5 years (Makarov, 2021). In terms of technology, they introduced the headset-based AR. In 2019 Google launched a feature for Google maps which features AR walking directions and which will be available on IOS and Android smartphones devices. This application can be used by simply by pointing the camera and information will be displayed in their surrounding area (Makarov, 2021).In 2016 Pokémon Go was greatly popular. This was a big year for AR and VR, people where buying devices such as VR headset to play the game (Altınpulluk, 2017). Shopping malls, grocery stores and supermarkets can be combined with IT industry. AR can assist shoppers in navigation to their required product. This mobile application has an innovative position and navigation system using technologies like AR core and AR. This mobile application has been tested at the KEELS supermarket in Sri Lanka (Jayananda et al., 2018). AR devices are improving and evolving through prerequisite such as sensors, cameras, display, and more. Figure 2.1 shows a demo of Pokémon Go being used on IPhone.

Figure 2.1: Pokémon mobile application

2.3 Applied uses of AR

AR is widely employed in the gaming and entertainment sectors. Applications such as snapchat or messenger uses AR while the user tries to take a picture, the camera detects the human face and put the filter in 3D space. Gradually games have also been introduced to AR. The most popular game that was mentioned earlier is Pokémon Go. As you walk around in the real-world Pokémon will appear on the device screen. The aim of this game is to collect as many different characters as possible. Apart from entertainment AR is being employed in various industries and also the educational sector. A research study by Mekni and Lemieux (2014) mentions that twelve distinct classes were been identified that use AR application such as medical, military, education, marketing and tourism. In the medical fields, an application was introduced for ultrasound, by using an optical see-through display this can view a volumetric image of the foetus superimposed on the abdomen of the pregnant women. The image appears realistic because it is correctly rendered. In the military sector, a real battlefield scene was introduced and augmented with annotation information. This helps soldiers to train as if they were in a real-life battlefield. In the sector of tourism, the tourist can use his mobile device to be able to view archaeological information, filters and sketches whilst visiting heritage sites. With the help of AR, the knowledge of the visitor is enhanced, and it makes the experience much memorable and fun (Mekni and Lemieux, 2014). Kesim and Ozarslan (2012) outline how AR Technology can also be experienced thanks to advancements with smartphones, making it more widely available to users. AR can be utilized for learning, entertainment, or a combination of both by enhancing a person's level of interaction with the real world, by using AR. Users can move around virtual images and view them from any specific points and angles, similar to a real object. Information conveyed by virtual objects can also help users to perform real-world tasks (Kesim and Ozarslan, 2012).

2.3.1 AR in Education

Hou et al. (2017) are proposing a mobile application for education in pre-school. This mobile application reality system (MARS) is based on mobile intelligent terminals, which is displayed in 3D form. This system has the functions of painting, literacy and listening to stories. While the child has their book open and while holding the mobile, they can observe the 3D objects and colour them. This application can improve the child's imagination, and learn the language while listening to stories and drawing. The advantage of this application is that it is a hands-on application, and it is fun to use (Hou et al., 2017). Another study introduces an application for children that suffer from chronic diseases such as diabetes. AR can be used to develop a therapeutic application, a tool to help these kinds of children. This application includes typical foods for breakfast or an afternoon snack. The application detects the image target which is the fish and virtual meals appears on it. As soon as the food is displayed on the dish the user can zoom in and out and move around the dish. The application has three groups of food which are grains, dairy and fruits. This application not only displays the food in 3D space, but also provides information about the dish such as the nutritional value of each portion and its real weight. This will help children to eat healthy and at the same time it makes much more fun to choose what to eat (Hou et al., 2017). In another study Radu (2012) argues about education impact of AR. Numerous surveyed papers showed that using AR is much more effective than using books, showing videos or using a PC during a lecture. It also indicates that content learned through using AR is much more memorable. Using AR also demonstrated that students have much more motivation and enthusiasm to learn, whilst also improving collaboration with other people. While working in a group, more enthusiasm was shown whilst using an AR map instead of while using a purely digital map. On the contrary some students were ignoring some parts of the experience or unable to perform a task because they find it difficult to use the application. During the group activities students were much more into the role play which brought up chaos. The teacher dominated the discussion and limited student engagement (Radu, 2012).

2.3.2 AR for Vocational Learning

The approach used by educators to effectively teach Augmented Reality must have an optimal mix of being both creative and informative. This teaching approach does benefit the students by maintaining a sense of interest and enthusiasm for a relatively complex subject. Although this approach is considered to be traditional, it has been proven to be the best fit in areas of related topics (Brilian et al., 2020). The educational system of Indonesia during 2013 reported increased interest in the curriculum of Science and Technology and was later identified as one of the highest achievements of the government during that period. This has been attained due to e-learning techniques, where students reported to have had more time to research and learn. Other researchers made observations regarding the teaching techniques used by lecturers during heavy equipment engineering powertrain education. Such techniques include the heavy use of PowerPoint slides. It was identified that due to lack of knowledge and experience in developing creative material using alternative learning media, such educators make use of basic PowerPoint slides to convey their material thus resulting in a lack of interest and engagement amongst students. The learning patterns used by educators will reflect on the students understanding and final grades. Hence, AR tools in the educational system make a positive contribution towards student achievements and attitude. Students reported having better engagement due to the efficiency and flexibility of AR technology. One of the media used in education, which resulted in a very positive impact, is 3D objects. Interactive multimedia using 3D objects or models can help educators to take a different approach during their lectures, which can increase the effectiveness and attract interest in using AR to stimulate the student's imagination and attitude. This approach results in having a better understanding and easier access to the learning material (Brilian et al., 2020). Another research paper studied teaching methods, where students were asked if they were open to new generation teaching methods. 53% of the students were open to "non-traditional technique", 21% were partly open and 22% very open to these new techniques. Overall, most students are not opposed to the idea of the new innovation. Another question that the students were asked was if they would be willing to practise physics or chemistry experiments based on AR and this resulted in 57% of the students willing to use the application during their lecture and 83% willing to watch hazardous experiments (Biró et al., 2017).

2.4 Other AR Projects

2.4.1 Local AR Projects

The Mediterranean Conference Centre in Malta, has an Augmented Reality Museum. In this museum people can relieve the sacra *infermeria*. In 1676 Grand Master Nicholas Cottoner founded the school of Anatomy and surgery at the Infirmary. This hospital was used by the British military in the eighteen hundreds. During World War Two ('WW2'), the building suffered severe damages and one third of the building was destroyed. In June 1798, the French took over the infirmary and carried out various structural alterations to improve the ventilation, sanitation, and lighting of the hospital (Malta, 2021). A mobile application was developed to deliver this cutting-edge experience that uses AR. People can witness the grand master during the blessing of the chapel and roam in the kitchen while slaves are working on their daily routine. The main features of this application are videos of historically accurate events that took place in the Sacra *infermeria*, witnessing the second war, creating a scene where people can dance with the main characters using the AR builder. During the WW2 the chapel was bombed and people can see how it looked like before the crisis happened. People can also explore the museum at their own pace while listening the detailed audio guide discovering multimedia content associated to every stop and last but not least a holographic display room where people can experience a close encounter of a digital life-size kind of Grandmaster De Valette (Centre, 2021). Another local AR project is based in Valletta The Secrets of Palazzo Falson'. This mobile application is based on a game which turns artefacts into animated objects. These objects are collected by the last owner of the palazzo who is Capt. Olof Frederick Gollcher a descendant from a Sweden family. The players must collect tokens and, clues that will help them along their journey inside this palazzo. This application has voiceover experience and audio-guided tour. These Augmented mobile applications are free to download and can be used on smartphones or tablets (Azzopardi, 2021). Figure 2.6 represents what will be shown when visiting the Mediterranean Conference Centre in Valletta.

Figure 2.2: Reliving the Sacra Infermeria

2.4.2 Foreign AR Projects

Lee and Choi (2014) presented an application which superimposes 3D Anatomy Models living in tideland in a sequence when the users make image targets in real time. They are attempting to improve the overall effectiveness of the proposed technique by implementing a Mobile Augmented Reality Application for smartphones using 3D animals, by selecting 10 animals living in tideland and creating 3D Animated Models of them. When implemented the application, 'Vuforia' SDK is being used so that the 3D tidal animals can be seen on a 2D plane through the use of a mobile device and its camera. This application and its uses' main targets are: children, those of which are studying about tideland and its inhabiting animals. After reading the book about tideland, the children can use smartphones to take pictures of a poster or an individual image upon which the 3D Anatomy model can be displayed in the image that is taken using the smartphone (Lee and Choi, 2014).

Zhao et al. (2018) propose plant learning and a way for students to understand nature. With the help of mobile applications, the author finds a way to assist in learning about plants. In previous research, an application that was developed and designed based on mobile visual search. The system using mobile intelligence could take pictures, audio, video and other information associated with plants. Nonetheless, the system still required some modification. The researchers modified their system by implementing AR in it, using similar technologies like this research study is going to propose they were able to build a mobile application with Unity. By selecting the AR button from the mobile application, it automatically requests usage from the phone's camera, and scans the plant. After the scan has finished the information about the plant will be displayed on the screen so that the student can interact with the 3D model of the plant by rotating it, zooming in and out, swiping left and right for information and rotating the model. This could increase the students interest and understanding about plants (Zhao et al., 2018). Figure 2.3 shows the result of detecting a plant and information displayed on an iPad screen (Zhao et al., 2018).

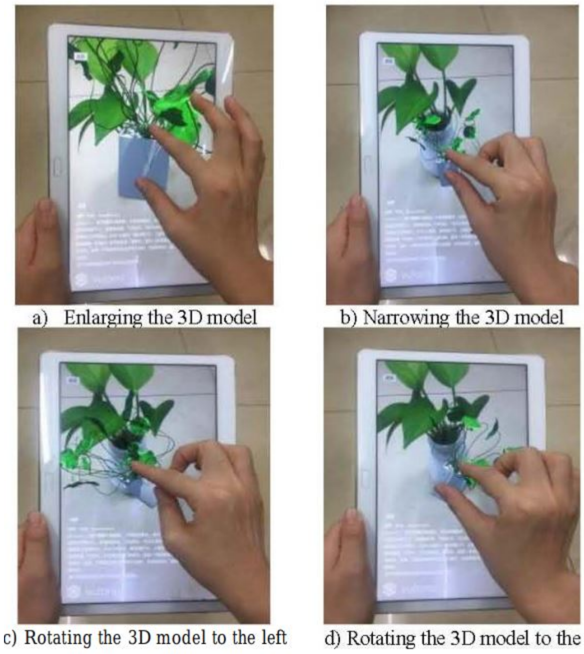


Figure 2.3: Augmented Reality display effect on a plant

Mambu et al. (2019) discusses AR to aid blind persons. In their daily lives they depend on other people in a research which was based on 5,329 blind people, it showed that they had a hard time identifying objects on their own as well as describing the object. Therefore, the authors developed a mobile application for blind people so that with a smartphone they are able to scan an object and the application will output a sound and give information about the object that the person is scanning. This application make use of "Vuforia" that contains the data sets so that when the camera is pointed at an object, the camera can identify it via markers, of which are identified by that of a single image. In this research the total of identified objects are 40 objects that consist of jelly powder, noodles and wafers. These objects are identified within seconds, and with the help of Google Assistant the user can open the application which will automatically detect objects that the user wants. If an object cannot be identified, then the application will keep on rendering until an object has been identified. The limitation of this application is that the user is not currently able to identify all objects, however in the future, the users themselves can add objects upon which the application could be converted and made available on different platforms (Mambu et al., 2019).

Li et al. (2017) proposes a technique for labelling objects in AR environment. This can be achieved by combining image analysis, search space and adaptive representations. To track the labels and 2D image Vuforia SDK was used for this study. Labels were positioned on the left, right and counter clockwise to be analysed. The results that are going to be evaluated are going to be using objective analysis of related parameters. Three search space methods were conducted and the result shows that the counterclockwise method possesses more processing time and lower optimization efficiency. These results were obtained without setting constraints to occlusion. Also, it can be conducted that from the three methods there were no significant change among different movements for all the three methods that can be seen in the below page.

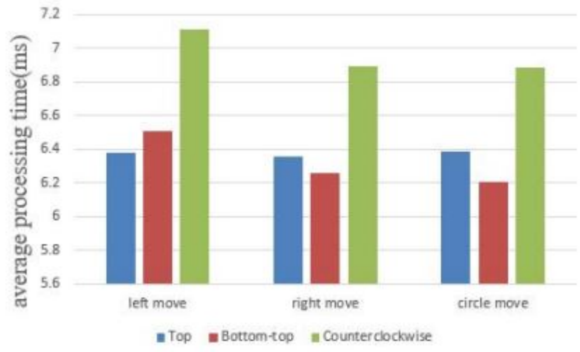


Figure 2: Experimental results of average calculation time.

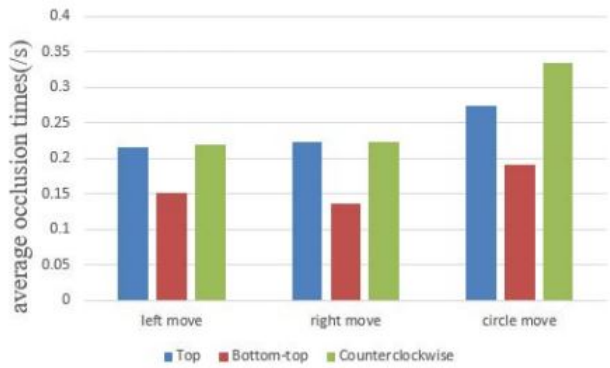


Figure 3: Experimental results of average occlusion times.

Figure 2.4: Experimental results.

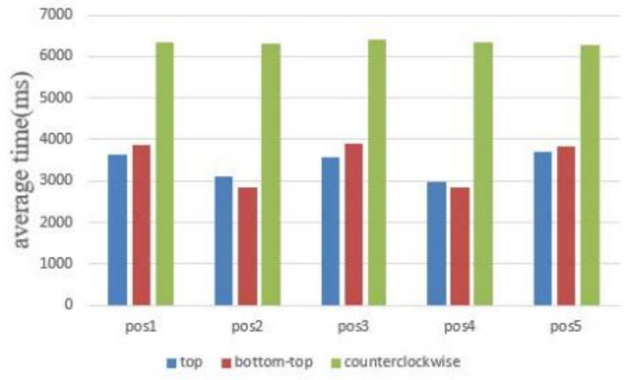


Figure 4: Experimental results of experiment 2.

Figure 2.5: Experimental result.

2.5 User Requirements for AR

To use an AR mobile application, one must know how to use the basic functions of a smartphone. For this kind of application, the camera is going to be used all times. Hence the latest smartphones which have a good camera with an adequate number of pixels. Having a 3G or 4G connection in your smartphone is also a benefit because if the user is not connected to WIFI they cannot load information from the cloud. A good battery is needed because an AR application drains the smartphone's battery. It is also suggested to keep a portable battery so when one is outside, they can charge the smartphone. Also, having a good quality processor such as Qualcomm Snapdragon for Android, prevents the application from crashing (Manufacturing and Design Innovation Institute, 2021).

2.6 Benefits and Limitations of AR

Augmented Reality consists of several advantages, some of which include the ability for multiple users to make use of mobile application simultaneously. As discussed in the foreign project section, members of the military can make use of such applications for training before being assigned to go to war. Such training would consist of making critical decisions and evaluations which would expose participants to a real-life environment of a battlefield at the safety of training camps. Whilst training, due to multiple reasons, training with AR content is considered to be more memorable rather than normal training without using AR. Mostly because since AR applications provide an experience identical to a real-life environment, AR eliminates or reduces the line between real and virtual worlds. Although of multiple advantages, AR includes some drawback as well. Drawbacks include AR being expensive to develop, produce and maintain apart from being very time-costly to test the application. After testing and development, non-technical users who are to make excessive use of such tool need training or briefing on how the application is intended to be used. Whilst some people argue that privacy is a concern when making use of such applications, others express concerns of excessive engagement to artificial environments in comprising to a real-life environment, hence considered as a drawback to using AR tools (Wireless World, 2021).

2.7 AR Frameworks for Unity Game Engine

Unity can be integrated with several AR frameworks so one can make unique unity features in a mobile application. Vuforia is a framework which is developed by Qualcomm which is a software development kit that enables users to build application with augmented reality. One can upload an image on Vuforia database, connect the Vuforia within Unity and develop some C sharp code, so when detecting that image target some generated graphics will be shown on that image target (Khanna and M, 2019). Another framework which can be used with Unity is AR Foundation which has specific packages for iOS, Android, HoloLens and Magic Leap. This framework can detect 2D image and 3D objects and features, body tracking, device tracking, plane detection, point clouds, ray cast and many more. AR Foundation does not implement any AR features but alternatively it defines a multi-platform API that allows users to perform common functionalities multiple platforms. A different framework which is commercial is Unity Mars. The price per year is $600 and one has only get one seat. When paying for this framework all the features will be available to use (Unity, 2021).

Technology Types	Operating System	Detection
AR Kit	iOS	3D Objects
AR Core	Android	Location Base, Surface Detection
Vuforia	Android, iOS	Marker Base
Unity Mars	Android, iOS	Real-World Objects

Table 2.1: Summary of AR frameworks.

2.8 Cloud Database Infrastructure

Developers nowadays are moving to the cloud (Yehuda, 2021). A cloud database is a scalable content database operating on the cloud that can be private, public or hybrid. A cloud database offers the benefit of not needing hardware as everything will be stored on the cloud. Those who have the permission to access files on the cloud can do so in their own time, at their home, from any device. Another important advantage is security as sensitive data is safer when stored in a cloud infrastructure. There is a lot of different cloud databases that one can use. Amazon web services has become the top market leader in the DBaaS space. It allows additional data management services such data warehouse and data pipeline which is data incorporating for simpler data management. This cloud database has a lot of features and easy to use. As a weakness it has a downtime as per amazon's schedule. Other types of cloud databases are Oracle, Microsoft Azure, Google Cloud, MongoDB and Open Stack. All of these cloud databases have the benefit of custom support, good documentation and easy to use (Yehuda, 2021).

2.9 Data-Driven AR Using Cloud Databases

Nilanjan et al., in Chatterjee et al. (2018) argue about Firebase framework and its functionalities. Firebase is beneficial for web applications which require real-time database that can be updated instantly every time the user makes a change. Firebase data is stored in a JSON format and can be synchronized continuously and can be used on any platform suck as iOS, Android and JavaScript SDK's. This framework handles most of the back-end. Firebase offers authentication which can authenticate every user by using email and password or phone number. The user iOS also allowed to use another authentication such as Gmail or Facebook. Firebase is also able to store images and files and it is supported by Google Cloud storage (Chatterjee et al., 2018). Firebase is also NoSQL based. There are few more cloud databases which are similar to Firebase such as AWS Mobile Hub which helps by monitoring, create and test mobile apps, Cloud Kit which is an Apple framework which works only on iOS and Parse Server that was released by Facebook (Khawas and Shah, 2018). Figure 2.6 shows how data is stored inside Firebase.

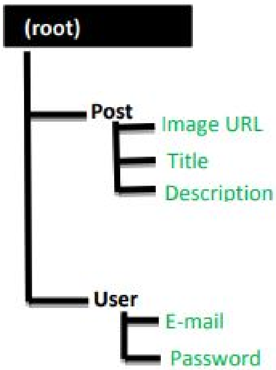


Figure 2.6: Firebase Data Structure

2.10 Augmented Educational Content On Real Objects

Tatzgern et al. (2014) proposed a multitude of techniques on how to place external labels on a 2D image. Since AR Cameras are always in motion, the labels float around the object they refer to. Desktop applications often only display external labels when the camera is not in motion. The specific technique is applied onto the label, as the 3D label is made up of a 3D annotation, a 3D pole and a singular anchor point so that the label is essentially attached to the object and not 'floating' around it. As this approach is aimed towards higher standards in terms of stability of the layout and general aesthetic, this study introduces strategies for said layouts in 3D object spaces. Figure 2.7 shows the result of a balanced label distribution (Tatzgern et al., 2014).

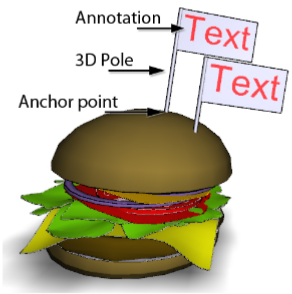


Figure 2.7: Labelled 3D object

2.11 Summary

Nowadays AR is a popular technology that combines the real world and the technology world together. Recent developments that use AR include the famous game called Pokémon Go. AR is being involved in other sectors such as medicine, history, mechanics, engineering and education. When students are getting involved with AR technology, they are demonstrating much more interest during the lecture. Moreover, instead of using a presentation, which might be boring, the lecturer can make use of AR and make the lecture much more interesting, with students becoming much more focused, as shown in previously discussed statistics. In order to use AR one must have a good quality WIFI connection and a good smartphone. Benefits and limitations of AR, cloud database and data driven AR has also been discussed.

Chapter 3

Methodology

3.1 Applied Research

Applied research is a process whereby one has to quantify how thoroughly we put in the knowledge we have learned from basic science to obfuscate problems. The key difference is a biased 'problem' that needs 'solving'. This process also involves designing, implementation and testing an application. It also well defines the performance of an application (W.Edgar and O.Manz, 2017).

For this study, a prototype was developed as a solution to deliver a lecture using a multi-user AR mobile application when using a 3D life-like model.

3.2 Aim of Prototype

Primar investigation was held to see if the users are familiar with the concept of AR and if they had used such AR application before. A first single model prototype was designed and tested throughout with thirteen participants in order to capture their views and obtain valuable feedback regarding needs and experience. With regards to the feedback obtained, the ability to scan own models and hence retaining data for future use and connecting with other users was understood. Hence this contributed to the development of the second prototype benefiting from key features which are data-driven AR framework. Furthermore, this helped in establishing if this application will help the users gain information while they are using this application during a lecture or to see if they prefer listening to their lecture reading from a PowerPoint. The main reason as to why this application was created is so that users can absorb knowledge in a fun way and to learn more about 3D Objects. This prototype was not aimed to be used by just one institute but for all kinds of institutes such as mechanical, science, computer studies, agribusiness and much more. For those who have not had the experience of using AR, it will be a good and interesting one, and for those who had used AR, this experience would help them develop their knowledge. People learn in different ways, hence why including various learning methods where all users can benefit from will benefit students and lectures alike. In more detail, the user can use the prototype in order to perform one of the following tasks:

1. Scan a 3D marker and upload it on Vuforia.
2. Create an account or sign-in.
3. Create labels and place them on the marker.
4. Resize the labels.
5. Rotate the arrow of the label.
6. Load, save and delete information on Firebase.

3.3 Research Pipeline

The research pipeline shown in 3.1 describes in a visual manner the different phases of this study, the flow of data, the different algorithms used and their evaluation.

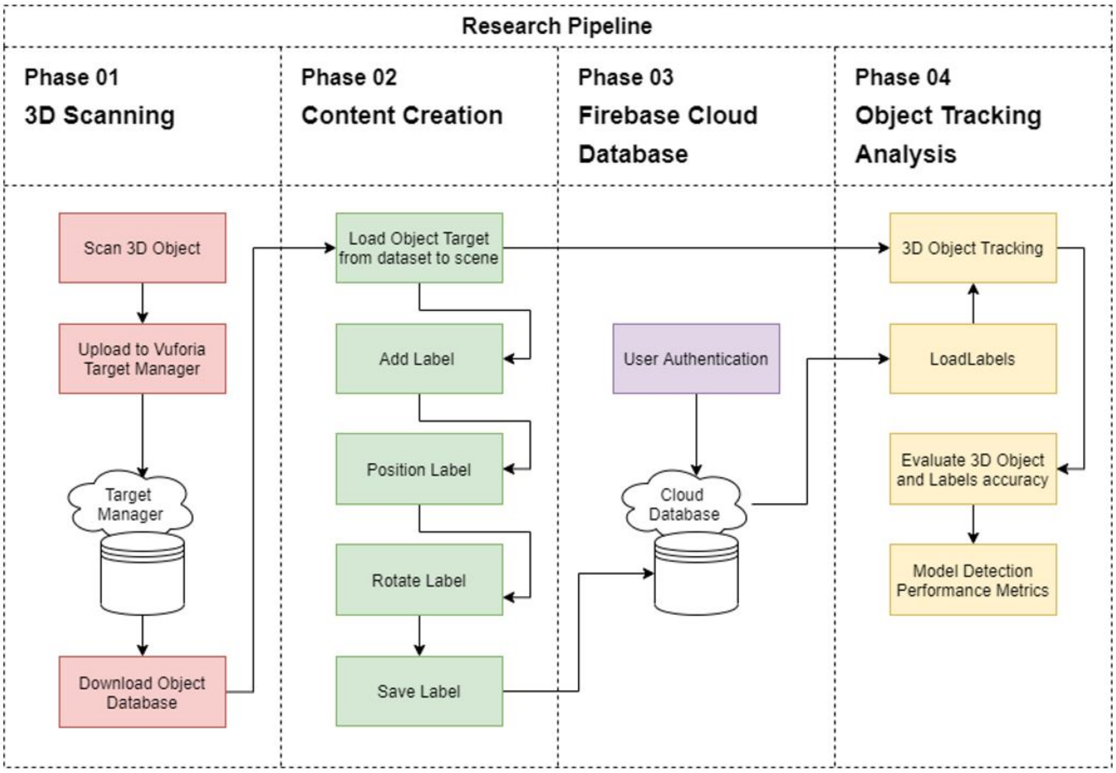


Figure 3.1: Research Pipeline.

3.3.1 Phase 01 3D Scanning

The first phase of the project pipeline is to scan a 3D object. It is possible to scan objects that are of fairly large size up to 1 metre. Objects in the real world can be scanned using the Vuforia Object Scanner.Figure 3.2 demonstrates how to scan a 3D object using Vuforia Object Scanner.

Figure 3.2: Vuforia Object Scanner

Vuforia Object Scanner is a free application to scan 3D Objects. One has to use a sheet shown on figure 3.3 to scan the object.

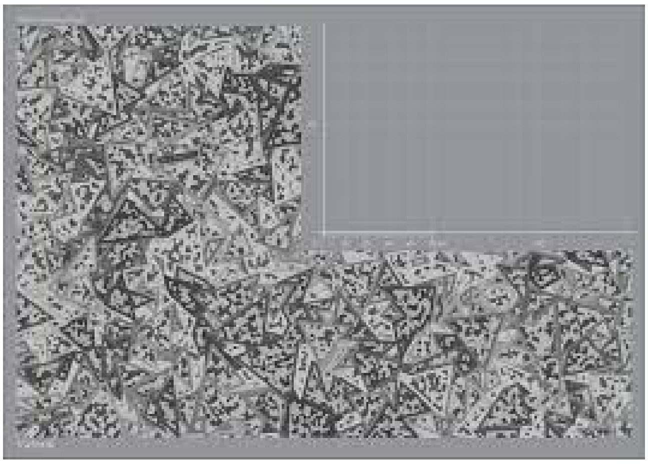


Figure 3.3: Vuforia Object Scanner sheet

Once the 3D object is scanned, one has to login in or create an account on https://developer.vuforia.com/. A database is created on Target Manager for each device that the application will be used on. If there is no database, the user must create one as it is quite important to have it for a device. The user then uploada their target as a 3D object as shown in figure 3.4.

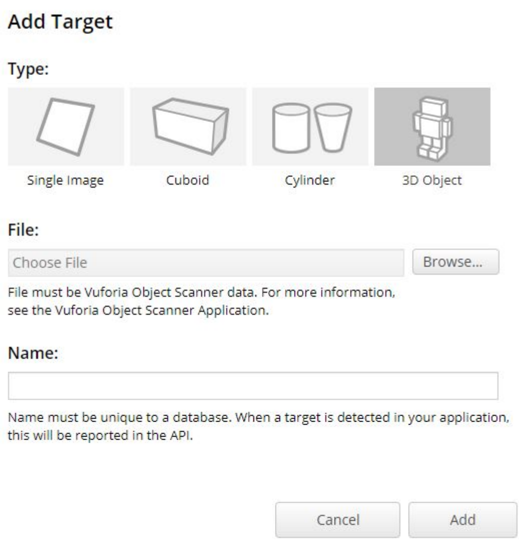


Figure 3.4: Add target on Vuforia

Figure 3.5 shows how it should look like when uploading a target to the database. The last stage of this phase is to download the object database from Vuforia online database by clicking on Android Studio, Xcode or Visual Studio as shown on figure 3.6. The unity editor will download an XML file. This will enable the extracting of the file from the application.

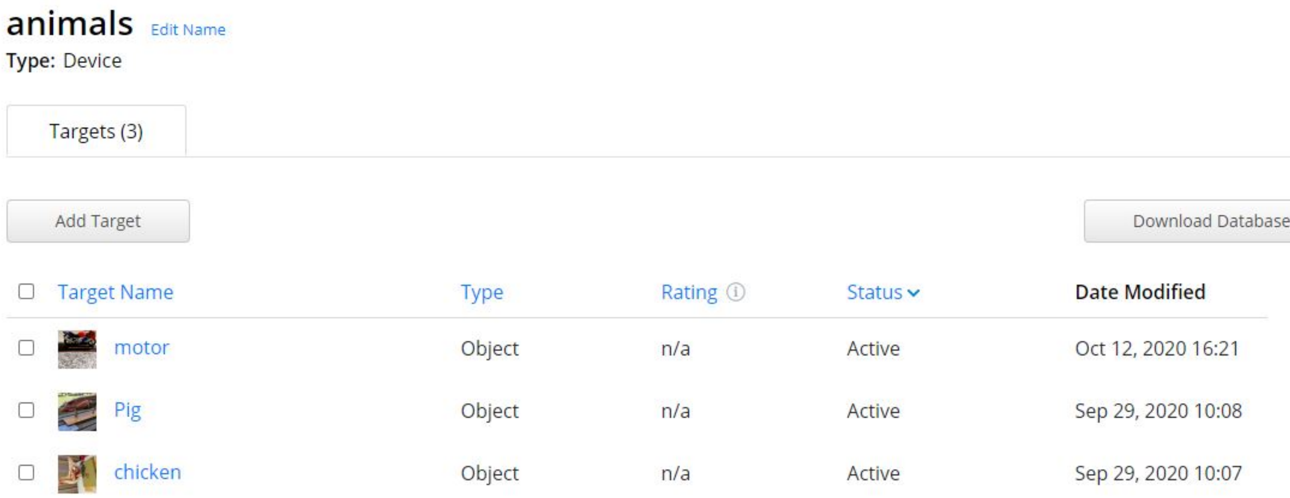


Figure 3.5: Vuforia Database

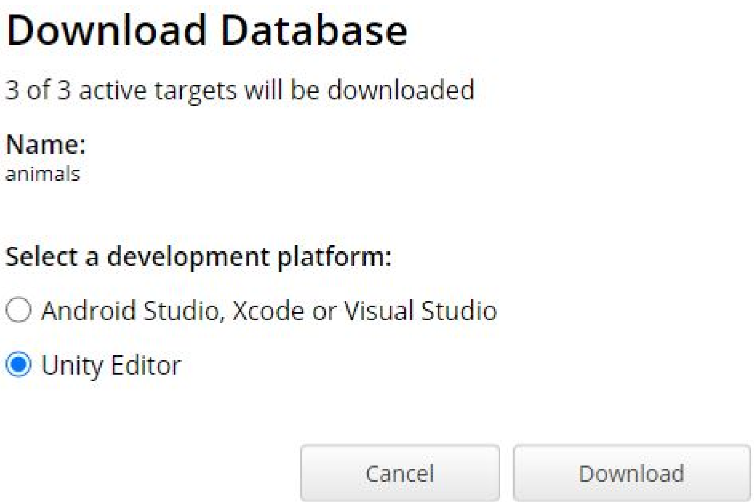


Figure 3.6: Vuforia Downloading Database

3.3.2 Phase 02 Tracking and content creation

Tracking and content creation is the second phase of the pipeline. This phase commences by loading the Object target from the downloaded dataset into the scene.

Location of the download folder.

Getting the location of the download folder from the smartphone and then the method unzip will extract the downloaded folder that was downloaded before from Vuforia target manager.

1. Set the outputfilename to "/storage..".
2. Set the foldername.
3. Extract the zipfile to foldername.

Creating the DataSet

OnVuforiaStarted method demonstrates when the application is running and Vuforia starts the method called LoadDataSet method will be called after. What this does is it locates the XML file, permission is granted from the user smartphone, the folder will be unzipped if is not yet unzipped and the data set is created.

1. Set filepath to default download directory.
2. Give permissions to read the file.
3. Check if the file already exists.
4. If the file does not exist unzip.
5. Create the dataset.

Checking if the XML file was created

If the data set can be loaded from the file path which is form the download folder. If this is a success a pop message will be shown on the user's screen saying "Targets Loaded". If the dataset is not active it will pop a message saying, "Failed to active DataSet". If object tracker failed to start a pop message will say "Failed to Start". If nothing fails a list of trackable behaviour is created.

1. If the data set is loaded from the file path.
2. Show a message that the targets are loaded.
3. Stop the object tracker.
4. Create a list for the trackable behaviour.

Creating the object targets

A foreach statement will go through the list of trackable behaviour and it will create the game objects. The game object properties will be assigned a name, scaling and a default trackable event handler.

1. Loop in the list of trackable behaviour.
2. If the name of the trackable behaviour is equal to "New Game Object".
3. set the game object name same as the trackable name.
4. Add a default trackable event handler to the game object.
5. Transform the parent of the game object.
6. Transform the local scale of the game object.

Content creation

When the user makes use of this application there are several functionalities to use such as adding a label and text to it, positioning the label on the 3D object, rotating the arrow of the label so it shows where the label is referring to and saving the label to Firebase, a cloud database. Figure 3.13 shows the labels that are loaded from Firebase onto the Pig 3D model. Figure 3.12 shows when the user is done creating the labels they are being saved onto the cloud Firebase.

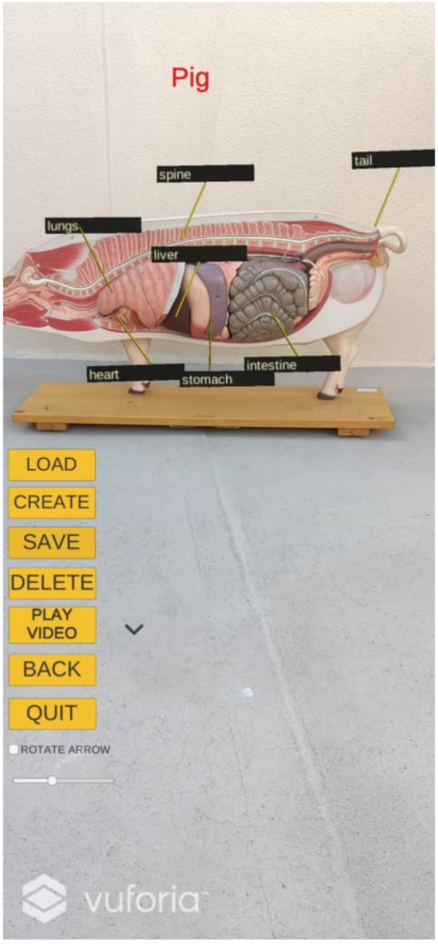


Figure 3.7: Pig 3D Model Labels Loaded

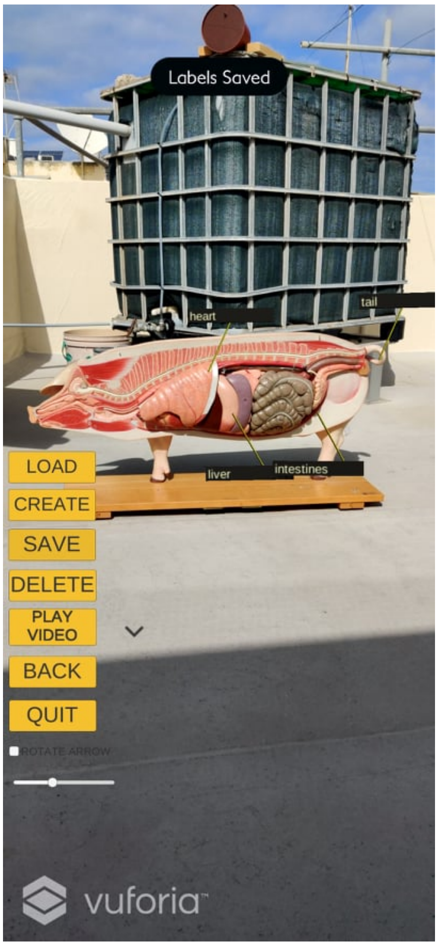


Figure 3.8: Pig 3D Model Labels Saved

3.3.3 Phase 03 Firebase Cloud Database

Cloud Database Storage

The prototype that was developed for this study was based on Google Firebase Cloud database. Firebase was chosen because of its interesting features such as email and password authentication, built-in security, support for different operating systems and real-time data. This prototype stores the email and password from the scene of login and register to authenticate users. This is one of the features of having a multi-user mobile application. Firebase is made up of two databases which are Cloud Firestore and Realtime database. Realtime database is the original Firebase database. It is used for mobile applications which need syncing with data in real-time. On the other hand cloud Firestore is more advanced since it is a much newer database. It is utilised in mobile app development and it is much more efficient since it builds on Realtime database with a more advanced data model. Therefore Realtime database was utilised in the prototype of this research, since it is low latency and requires syncing. Realtime database saves the information of the labels that are going to be created by the authenticated user. Firebase automatically creates the relationships between the user and the labels, and meanwhile the tables are being created via the code. The table gets created only once, then it updates itself with the aid of the code depending on the 3D model. Phase 03 makes use of Firebase which is a cloud database by Google, where the information of every label is stored. Every user that is going to be using this mobile application must authenticate themselves. The application has a scene where one can register or login, hence why it is called a multi-user mobile application since it is not bound to only one user. In Firebase when a user account is created and logged into, the created label is referenced to the logged-in user. Figure 3.9 shows how the data is stored inside Firebase in JSON format.


```
{
  "User" : {
    "Dp0wKKKi9peRziULQvnl8UPMSVj1" : {
      "Email" : "a.a@hotmail.com"
    },
    "Labels" : {
      "Dp0wKKKi9peRziULQvnl8UPMSVj1" : {
        "Pig" : {
          "ArrowPosX" : [ 3.756, 2.20331, 3.756, 3.756, 3.76994, 3.756, 3.756, 3.756 ],
          "ArrowPosY" : [ -3.551, -4.46868, -3.551, -3.551, 0.835883, -3.551, -3.551, -3.551 ],
          "ArrowPosZ" : [ 0.272, 0.5, 0.272, 0.272, 0.5, 0.272, 0.272, 0.272 ],
          "ArrowRotW" : [ 0.934231, 0.95882, 0.900788, 0.902308, 0.961262, 0.895371, 0.931438, 0.939551 ],
          "ArrowRotX" : [ 0.320731, -2.98023E-8, 0.364001, 0.357967, -2.98023E-8, 0.379095, 0.296517, 0.292395 ],
          "ArrowRotY" : [ 0.0224062, -4.84288E-8, 0.0873275, 0.0712414, -6.51926E-9, 0.0643183, 0.148644, 0.122167 ],
          "ArrowRotZ" : [ -0.154408, 0.284015, -0.220132, -0.229402, 0.275637, -0.224633, -0.149684, -0.129705 ],
          "LabelPosX" : [ 0.34832, 0.223291, 0.588267, 0.884018, 0.178703, 0.884018, 0.686097 ],
          "LabelPosY" : [ 0.319684, 0.398746, 0.423914, 0.504986, 0.116287, 0.504986, 0.253877 ],
          "LabelPosZ" : [ 0.218109, 0.264848, 0.428945, 0.30555, 0.155792, 0.30555, 0.176652 ],
          "LabelRotW" : [ 0.945797, 0.958953, 0.926945, 0.930383, 0.925683, 0.922598, 0.942072, 0.945795 ],
          "LabelRotX" : [ 0.318257, 0.256047, 0.374228, 0.364942, 0.376706, 0.384138, 0.321171, 0.311566 ],
          "LabelRotY" : [ -0.0456418, -0.0548004, 0.00871104, -0.00574368, -0.00549191, -0.016961, 0.0828644, 0.0578493 ],
          "LabelRotZ" : [ 0.0458031, 0.108835, -0.02549, -0.0342325, -0.0342588, -0.0310317, 0.0498324, 0.0710721 ],
          "LabelScale" : 0.025,
          "LabelText" : [ "Heart", "Lung", "Liver", "Stomach", "Intestine", "Tail", "Spine" ],
          "ObjectTarget" : "Pig"
        }
      }
    }
  }
}
```


Figure 3.9: Data inside Firebase.

3.3.4 Phase 04 Object Tracking Analysis

The final phase is object tracking and analysis. When the application is opened the 3D object is loaded from the dataset from Phase 02, with the application able to track again the object target.

Track 3D object.

One can understand that when the ARCamera game object is found from the scene it will get the active trackable behaviour name and displays a message on the scene saying "Trackable Found". When the target is detected, the labels can be loaded from Firebase. These figures are about the loading from Firebase.

1. Find the AR Camera game object.
2. Set the state manager.
3. Create a list of trackable behaviour.
4. For each trackable behaviour set the trakable name.
5. Set the game data object target equal to the trackable name.
6. Transform the parent.
7. Transform the text.

Load from Firebase

Get the instance from Firebase database, get the reference from User/Labels and get the values async. If it is faulted, an error will be displayed notifying the user that there is no data. Alternatively, it will get the results and creating the snapshot according to its child. Clearing all the lists from the class GameData so all the data inside the lists will be correct.

1. Initialise the firebase instance and put the reference.

2. Get the result and initialise the data snapshot.

3. Get the key from the current logged in user

4. Clear all the lists from the game data class

Parsing Data types

All the lists from GameData class which are myLabelsPos, myLabelsRot, myLabelsText, myLabelsScale, myArrowPos, myArrowRot, targetId and myObjectTarget are being filled with data from Firebase. The data is being parsed before inserted because Firebase requires only string as a data type. Analysis can be taken when moving the mobile device around the 3D marker. Also, evaluation of the accuracy of label positions in 3D space was performed. Three scripts were created so accuracy and scaling for the labels will be as accurate as possible when the 3D object is detected.

1. If the key from the logged in user is equal to the snapshot child key.

2. Get the count on how many child the snapshot "/LabelText" has.

3. Loop in how many children the snapshot "LabelText" has.

4. Parsing all the snapshot child to float and add the values to the list in game data.

Add labels

A label game object was created so that the user can state the organ name. This game object is a textmesh which is a vector 3 and additionally the camera rotation is being assigned to it. The importance of the camera rotation is essential because when the user is detecting the 3D object from a certain angle, the label must be facing the camera. After that step the GameData lists are being filled which was mentioned in previous figures.

1. Create a new game object.

2. Find a game object called "Canvas/myNewLabel".

3. Create an input field.

4. Set the textmesh prefab, vector 3 and camera rotation to the new game object.

5. Transform the created game object parent.

6. Transform the llocal scale of the game object.

7. Set the game object text from the input field.

8. Destroy the text box game object.

9. Destroy "Canvas/SaveButton(Clone)".

Rotation of the label arrow

After the label is created, an arrow attached with the label is created as well. This has to indicate which part from the model is being referenced to. A functionality that is being taken care of by this script is transforming the X and Y of the arrow together with the up and right using the property RotateAround. This method is being overridden from the touch manager script that will be explained below.

1. Set the rotation speed to 20.

2. When dragging the mouse get the x and y axis.

3. Transform the up and right using the rotate around the x and y.

Label scale.

The scaling of the label, how large does the user wants the label to be. This will change the transformation of the label game object changing the value with a slider.

1. Get the slider value.
2. For each game object transform the local scale to the new slider value.
3. Set the myLabelScale.

Touch Manager

This will allow the user to handle the labels from their smartphone by dragging it. The touch manager script was created to handle the touch from the user smartphone since modern smartphone screens are all touch-based. The rotation speed is set to 10 because when rotating the arrow needs to be slow not fast. Since this method is being overridden by the method "Rotation of the label arrow" the rotX and rotY are changing while the user is rotating the arrow and then the transformation of the arrow child is being assigned by a quaternion euler. Next the game data list is being assigned the value of the local position and the rotation of the label. In certain devices such as OnePlus, the camera was not focusing automatically on the 3D object, so a script was created to handle this issue.

1. Set the variable to true to rotate the arrow.
2. Set the rotation speed to 10.
3. Set the variable to the value of mouse x multiplied by the rotation speed multiplied again by the Mathf.Deg2Rax.
4. Set the variable to the value of mouse y multiplied by the rotation speed multiplied again by the Mathf.Deg2Rad.
5. Transform the child rotate around.
6. If the transform child is greater the -0.3, transformation the child rotation to a quaternion euler.
7. If the transform child is greater the 0.3, transformation the child rotation to a quaternion euler.

8. Get the mouse world point plus the off set and assign it to a variable.
9. Transform the child position.
10. Get the local position.
11. For each game data label assign the arrow position and arrow rotation.

Smooth Camera

When the user is going to start using the application, Vuforia is going to be initialised and its instance is going to be updated. To detect a 3D object the camera is going to focus and smoothen its frames on the object in front of it. Additionally, to evaluate performance, different mobile devices were used to test this AR mobile application.

1. Set the tracking to true.
2. Set the rotation to a new queue using smoothing frames.
3. Set the position to a new queue using smoothing frames.
4. Get the Vuforia instance on initialized.
5. Get the Vuforia instance on trackable update.

3.4 Prototype

3.4.1 Game Engine, Cloud Database and AR Multimedia Tools

Unity is a multi-platform all-inclusive development tool which is utilized in interactive content mainly games in both 2D and 3D content (Luyao et al., 2018). It is fully integrated executive game engine which builds visualisation and real time 3D animation. Unity benefits from a powerful virtual scene editing function, providing a superior logic management function. Custom scripts can also be put down in JavaScript or C sharp. Besides Unity also benefits from a very powerful physics engine which can be put in practice in order to simulate realistic physical phenomenon as long as the rigid body, gravity and other physical properties are attached to the game object respectively. It also has various functional systems which include terrain editor, particle system animation and more. On the other hand it has a superior model import interface, useful and helpful programming interface and practical development tools. The above-mentioned features contribute in providing powerful positions for the development of Unity-based systems functions. Putting the above features into consideration, users can easily develop virtual reality engineering with real mechanical effects, strong communication and good immersion experience (Luyao et al., 2018). Since the system benefits from the mentioned advantages the Unity engine was chosen as a development base for my project respectively. Vuforia SDK was used to track real-time 3D objects and to build AR application for mobile devices such as Android and iOS. Vuforia Engine can be accessed through the Unity package manager by installing a script from Vuforia package repository. Once downloaded in Unity, an empty model target was created. A script was created to load 3D object targets from the device which was downloaded from Vuforia target manger. Once the game objects were created, trackable event handler was added to it. Hence when the game objects were created, the AR camera could track the 3D object by its trackable name.

3.4.2 Differences between Single Model and Data-Driven AR Framework

The user experience of the prototype is based on two similar but different projects. The single-Model prototype only had one model which is a life-like 'chicken' model and it was limited to only one user. The label's information is saved inside a serialized binary file called gamesave.save. It was also aimed to be used by the Agribusiness Centre within the Institute of Applied Sciences at MCAST. Figure

3.10 the user experience of the prototype is based on two similar but different projects. Figures 3.11, 3.12, 3.13 shows when the targets from the dataset are loaded, the labels are saved on Firebase and loaded when the application is opened.

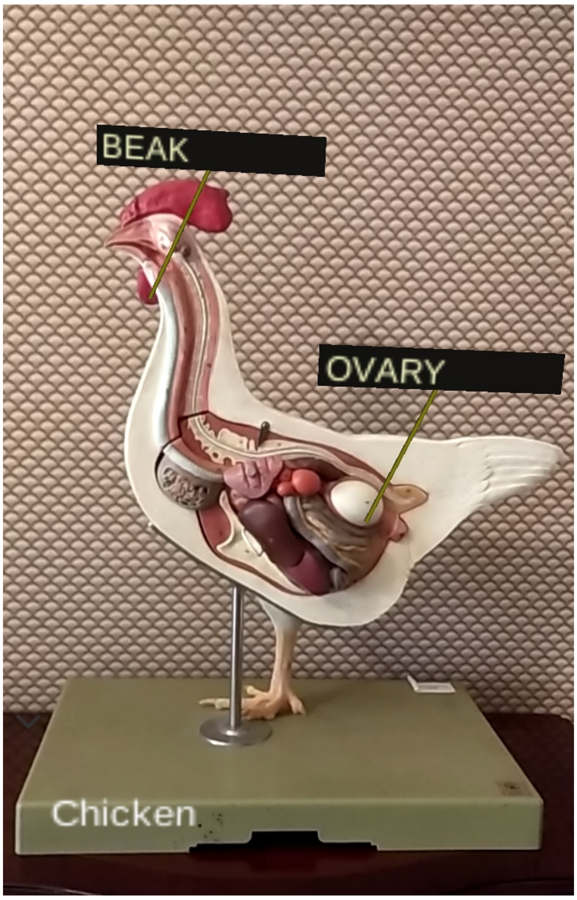


Figure 3.10: Labelled Chicken 3D Model

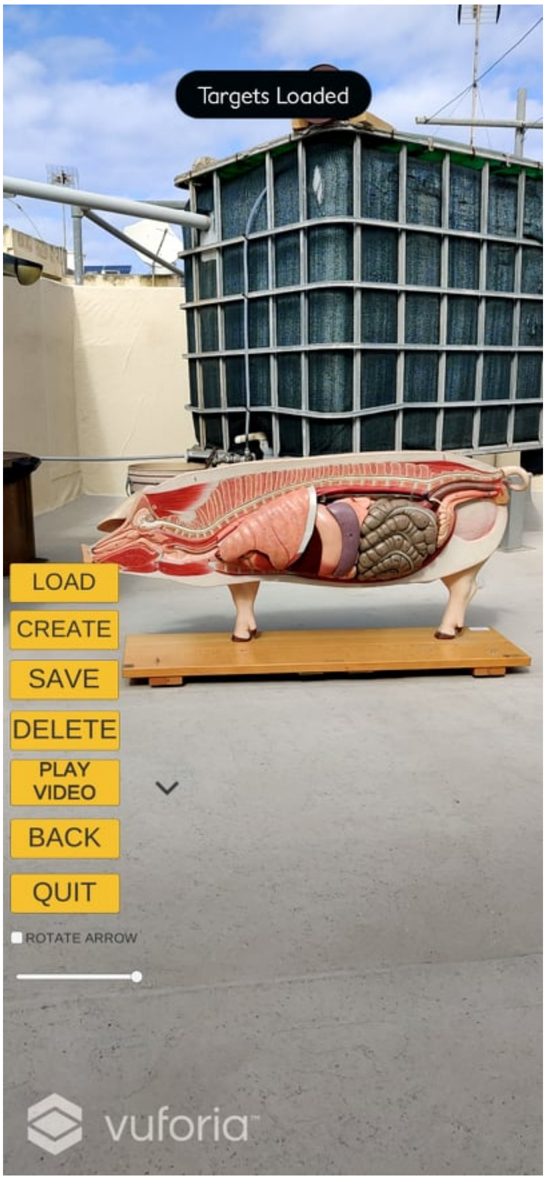


Figure 3.11: Pig 3D Model Target Loaded

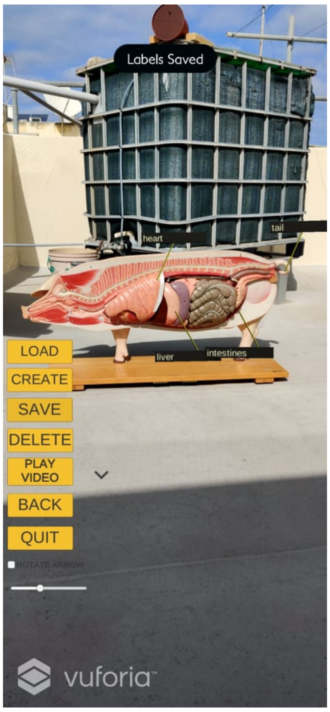


Figure 3.12: Pig 3D Model Labels Saved

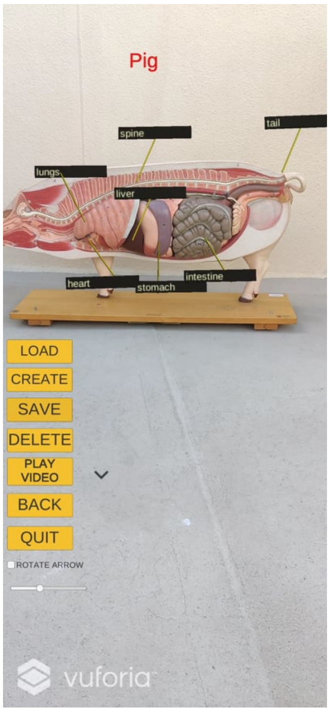


Figure 3.13: Pig 3D Model Labels Loaded

3.5 Research Methods

3.5.1 Quantitative Research

A quantitative study is simply the gathering of countable data and thus performing computational, numerical and statistical techniques (Goundar, 2012*a*).This accumulates information from readily-existing users, such as sampling methods and sending out online surveys, questioners and polls. The result is in a numerical form. Therefore we can simply say that quantitative data consists of a large number thus a large population means more numbers that can be analyzed, therefore more data hence a more accurate final result.

3.5.2 Qualitative Research

On the other hand this type of data utilizes a more conventional approach where the individual in a research is asked an open-ended question (Goundar, 2012*a*). Hence, most of the time, this type of is non-numerical. Here data is mostly gathered through a conversational approach such as interviews, questionnaires, case studies and more. This type of data is mostly used to help shed light on understanding opinions,motivations and other crucial reasons. Thus this method aids in providing insights in the situation hence developing an idea or hypotheses for the study, which will eventually discover opinions and other fields of thoughts deeper in the problem.

3.5.3 Mixed Methods Research

Mixed methods is a method that integrates, collects and analyses both quantitative and qualitative data (Goundar, 2012*b*). This method is mainly put into practice when this integration provides a better and clearer understanding of the arised research problem. By mixing these research methods together, one gains a deeper understanding and corroborates, meanwhile showing the weak inherent as in to using each method by itself.One of the best advantages obtained from this phenomena is triangulation which simply is the use of several means, methods, researches and data sources in order to examine the same phenomena. Triangulation provides a more clear and accurate approach from different points utilizing various methods and techniques. For a perfect triangulation one must carefully analyse the information provided showing both its strengths and weaknesses. This data is mainly put into practice when an individual wishes to look at a research from different angles of analyses and thus clarifying unexpected discoveries.

3.6 Research Methods Justification

Given that this study seeks to explore both the accuracy and performance metrics of the developed prototype, application together with the user's experience and applicability in a learning scenario, a mixed methods approach as defined above is highly appropriate. Quantitative benchmarks and metrics were collected to profile the application. Qualitative techniques which include a questionnaire and short interviews were then employed to capture the user's experience. The AR mobile application it self can evaluate the accuracy of the label and performance of the application. Also the AR mobile application can be used by multi users to dynamically scan 3D objects and create AR content around it. After creating the AR content, these can be saved on the cloud. By filling the questions from the questionnaire the author will be able to collect data which demonstrates whether the AR mobile application can truly facilitate teaching and learning that involves real objects and scenarios.

3.7 Questionnaire Design

The aim of this questionnaire is to determine whether the user prefers using the AR mobile application during a lecture or the traditional way i.e. reading notes, presentation and videos. The questionnaire was designed to gather qualitative data. Microsoft forms was used to administer the questionnaire online, and this was completed in by a number of different respondents to gain insights about the AR mobile application. The questions that were asked in the questionnaire are as follows:

1. What is the position of the user.
2. If it was the first time using an augmented reality application.
3. What they liked the most about the agribusiness AR mobile application.
4. How was the navigation of the agribusiness AR mobile application.
5. A question about the application if it is more efficient using the mobile application than learning in a normal classroom since it can be used anywhere at any time.
6. With the exciting features the mobile application has does it help to achieve the goals, and how.
7. Rating the user experience using the mobile application.
8. Would the user prefer to use the mobile application instead of traditional resources like notes, presentations, or videos in order to learn.
9. How the user found the positioning and rotation of the labels in the application.
10. What improvements would the user suggest on the existing features like labelling, saving and loading interface.
11. Which other features does the user think the agribusiness AR mobile application can include.

3.8 Quantitative Data Analysis through Prototype Benchmark

The prototype was tested on campus at the MCAST Agribusiness institute. Interviews were conducted with a total of thirteen participants. The respondents were invited to make use of the prototype, following a 10-minute research interview for a quantitative data analysis in order to interpret the data gathered and evaluate the participants perception of the prototype.

3.8.1 Confounding Variables

A confounding variable is an impact that alters the effect of a dependant and independent variable. The unnecessary influence is used to influence the result of an experimental design. In other words a confounding variable is an additional variable introduced to an equation which was not accounted for. This can destroy and experiment and deliver ineffective results (SoftSchools, 2021). Since a small amount of participants participated in the interview, with different aptitudes, knowledge and IT skills, this may possibly lead to results which may differ than those that would have been obtained from a larger number of participants. With a smaller amount of data there would not be enough of results to compare. On the other hand having a large amount of data it will deliver effective results.

3.8.2 Pre-experience

A quantitative approach was used to form a questionnaire for this part of study. Thirteen participants were selected to respond number of questions about the AR mobile application and if the users prefer learning the traditional way or using the AR mobile application. The traditional way of learning consist of presentations, notes and a poster with a labelled animal. To address the questions which was obtained by using the AR mobile application to detect the 3D object.

3.8.3 Post-experience

Following the questionnaire the participants tested the AR mobile application and afterwards, an interview followed to determine whether the participants had a different opinion than before about the learning outcome of the AR mobile application and if the users prefer learning the traditional way or by using the AR mobile application. The experience included creating a number of labels in 3D space, scalinge them and position them at the right place.

3.9 Ethical Considerations

The study was carried out in a manner as to avoid any harm on real-life animals. The questionnaire was filled out anonymously and the identity of the participants who took part of the interview remained confidential. No personal data was gathered or stored during the interview and the questionnaire. With regards to moral harm, there was none since the aim of the application is to help the user in education. Furthermore, since the prototype application is not available to any business, there was no harm to any business.

Chapter 4

Research and Analysis

Following up on the methodology the AR mobile application was tested by thirteen participants and then results gathered from the user perspective are discussed and analysed. Also, multiple test cases were carried out on the AR mobile application to be analysed on different 3D models, accuracy and angles and cloud database.

4.1 Quantitative Results and Analysis

In this section quantitative data will be presented, analysed and discussed in relation to model detection performance in different conditions, label accuracy, different angles and hardware performance. For each result, a comparison with other studies is made.

4.1.1 Model detection in different environments

The AR mobile application was tested in the outdoor sun, indoor artificial lighting and indoor daylight. Different mobile devices and different angles were also used, in order to test the application and see which better test case should be a good practise. The profiler that is integrated with Unity is going to be used to get the result of the AR mobile application rendering. Rendering is the process of frames and colours in order to create a life like image on the screen. A chart is going to be represented to show the result and a discussion describing the chart.

Outdoor sunlight

The model that is going to be tested is a Porsche car, which is a fairly sized 3D object which can be seen on figure 4.1 was tested by a OnePlus 8 mobile phone.

Figure 4.1: Porsche 3D Model.

The distance from the 3D model and the mobile phone was 4.4 inches. When it was greater than 4.4 inches, the labels started becoming jittery and detection started being lost, even when there waere labels loaded from Firebase.

Indoor daylight

The model that is going to be tested is a motor bike, which is a small 3D object that can be seen on figure 4.2. This model was tested by a OnePlus 7 mobile phone. When testing the AR mobile application in indoor daylight, the motor 3D model it was still detected from 60inches from the mobile device. To achieve this kind of distance, during the development a smooth camera script was developed so that in indoor daylight the frames would be smooth and focused on the 3D object. To load the 3D model a script was also made to unzip and load models from a text file that was downloaded from Vuforia.

Figure 4.2: Motor 3D model.

Indoor artificial light

The model that is going to be tested is a motor bike, which is a fairly smaller 3D object than the indoor sunlight model. This model can be seen in figure 4.3. This model was tested using a Xiaomi Redmi note 8 mobile device. When testing the AR mobile application in indoor artificial light, the motor 3D model it was still detected from a distance of 70inches from the mobile device. To achieve this kind of distance the script was mentioned before improved the camera focus. Comparing this version of the application with the first one, the author noticed that it obtained quite a large distance, whilste the labels and model were still being detected.

Figure 4.3: Motor bike repsol 3D model.

4.1.2 Other studies regarding model detection and lighting

Just as Calle-Bustos et al. (2019) stated, the lightning condition effects the capture of the image, especially when the camera has a lower resolution. Even though the camera pixel was only 2-megapixel, it needed much more light in order for the image to be detected. From the above findings this can be confirmed. When the indoor artificial lightning had low resolution the accuracy of the labels was not good enough to go around the 3D model. Compared with the other models when there was good lightning the angle was much less and the labels were still detected.

When a model is detected, labels can be placed by the user. In the next section the accuracy of these labels at different angles on differently types of 3D objects will be examined.

4.1.3 Camera angle and label accuracy

The approach that was used based on the labels is that, the user can create a label and place it anywhere in 3D space on the 3D model. The user can then rotate the arrow to indicate which organ is labelled and afterwards, the user can choose the best angle for the label. Hence for example going on the left side of the 3D model the label loses it's position and therefor the user needed to re position it. As shown in figure 4.4 the labels are still being detected from an angle of 30 degrees. To achieve not having jittery labels and loosing detection, a script was prepared during development. The label that was created was being set to the camera rotation, so when the label is loaded, it will be displayed from that angle. The local position, rotation and scale value was also being set to the label. The scale is how big the label is going to be displayed. This is changed to a size that the user wishes. If it was left to a default size it would get jittery depending on the size of the 3D object, thus a slider was considered for this issue. For the rotation of the label, the speed was set to 30, so that when rotating it would be easy to rotate. By getting the X and Y from the mouse and also if the rotation is smaller than -0.3 it would transform the child of the rotation to -30f, or else, if the rotation is bigger than 0.3 it would transform it to 30f.

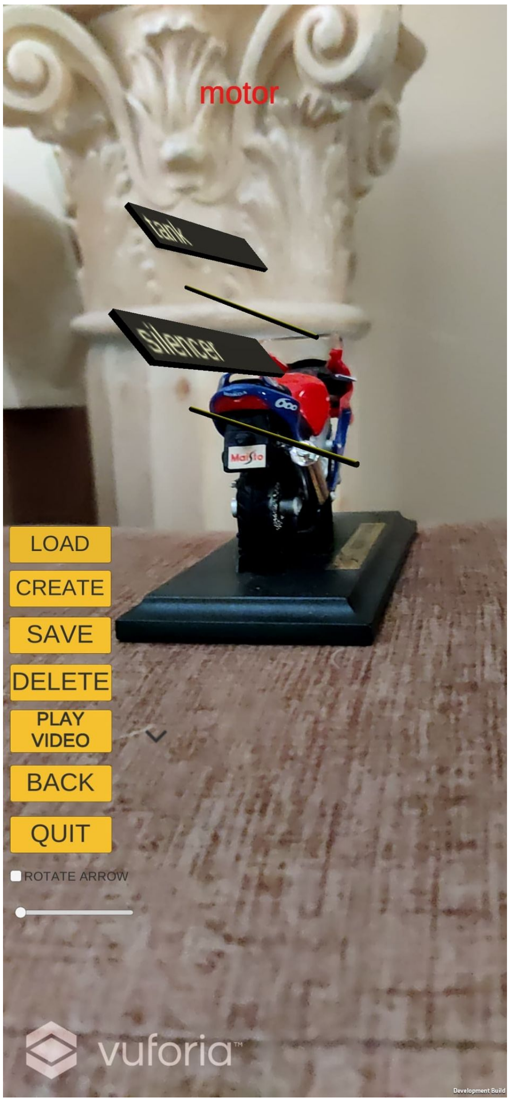


Figure 4.4: Motor label from 30 degree of angle.

Figure 4.5 shows that the labels are still being detected from an angle of 10 degrees. The labels were not being jittery and they kept on being detected.

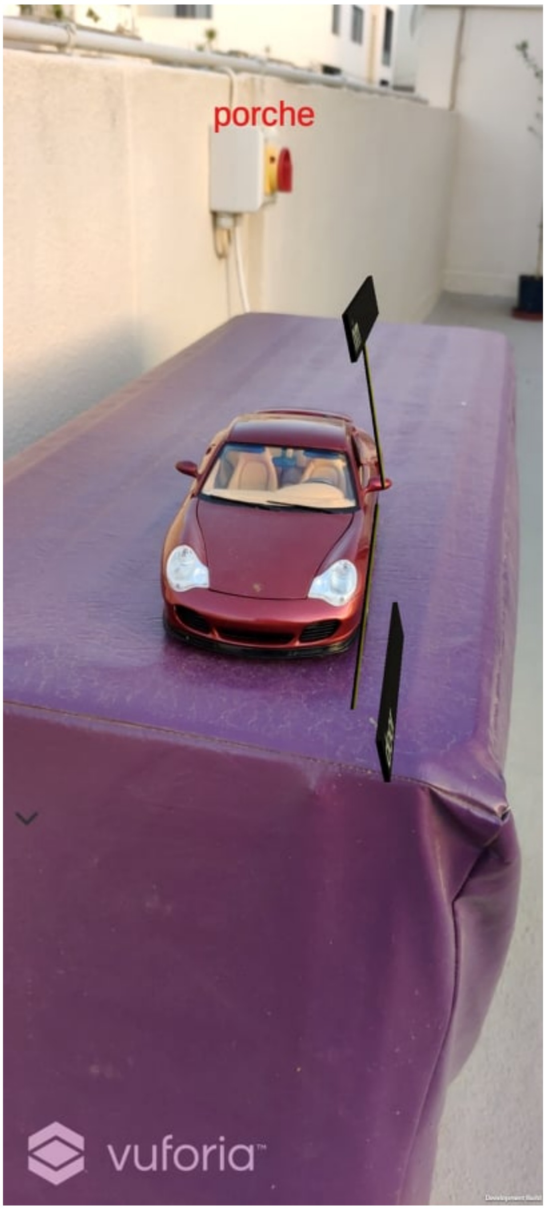


Figure 4.5: Car label from 10 degree of angle.

As shown in figure 4.6 the labels are still being detected from an angle of 50 degrees. When going more to the left side of the 3D model, the labels and 3D model were still not being detected. The issue is because of the model is small to go around it. The lighting was perfect to detect the model and test the labels' accuracy. There was no jittering and the labels took place instantly when loaded.

Figure 4.6: Motor bike repsol 3D model Labeled.

Difference between a Large and small 3D Model

While having different angles the small 3D model demonstrated mostly perfect alignment. Only for the zero degrees missed the alignment, and hence lost the label detection. The below table shows the results of the negative angle and positive angle of the small 3D motor model.

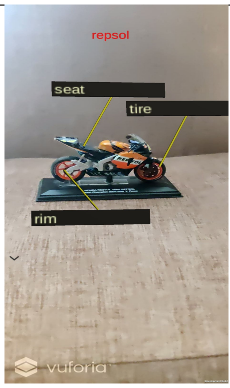
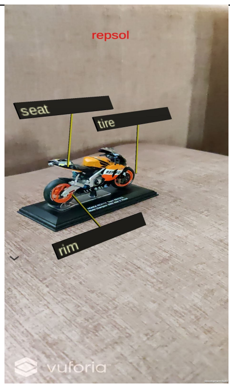
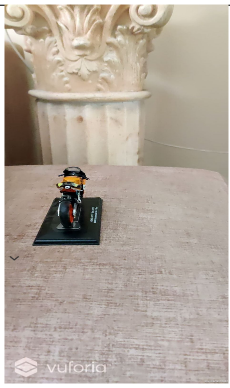
Angle	Output	Alignment
-90		Perfectly Aligned
-60		Perfectly Aligned
-30		Slight Misalignment
0		Missed Alignment

Table 4.1: Results of motor small 3D model on negative angles.

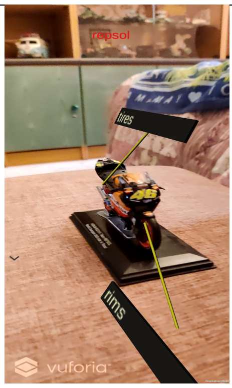
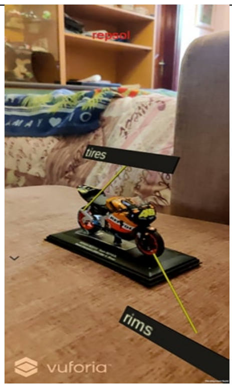
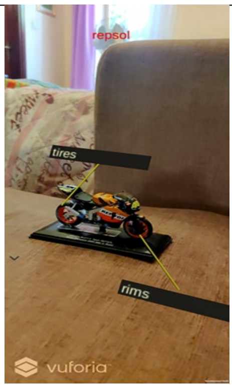
Angle	Output	Alignment
30		Perfectly Aligned
60		Perfectly Aligned
90		Slight Misalignment

Table 4.2: Results of motor small 3D model on positive angles.

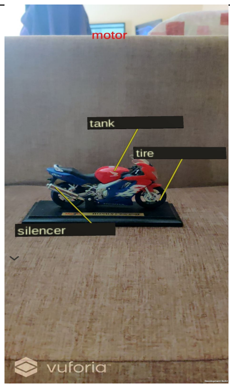
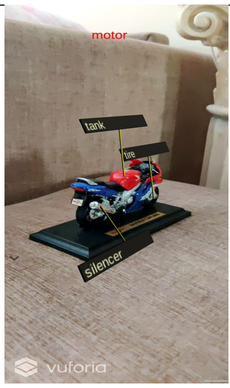
<table>
<tr><th>Angle</th><th>Output</th><th>Alignment</th></tr>
<tr><td>-90</td><td>
</td><td>Perfectly Aligned</td></tr>
<tr><td>-60</td><td>
</td><td>Perfectly Aligned</td></tr>
<tr><td>-30</td><td>
</td><td>perfectly Aligned</td></tr>
<tr><td>0</td><td>
</td><td>Perfectly Aligned</td></tr>
</table>

Table 4.3: Results of motor 3D model on negative angles.

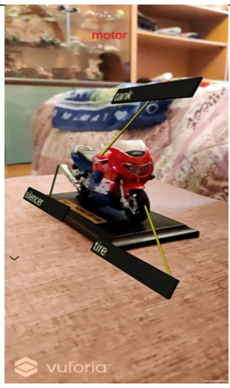
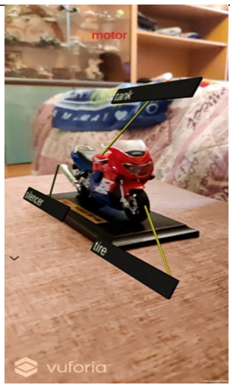
Angle	Output	Alignment
30		Perfectly Aligned
60		Perfectly Aligned
90		Perfectly Aligned

Table 4.4: Results of motor 3D model on positive angles.

Whilst being viewed from different angles, the motorbike 3D model shown in tables 4.3 and 4.4 demonstrated perfect alignment. Since it is larger than the other motorbike, the alignment was perfect for all the angles and the labels were detected at all times.

Other studies

Furthermore, with regards to accuracy and detection Zhao et al. (2018) concluded that those plants that had less feature points had lower accuracy of feature matching. This affected the display and the recognition was not good. Comparing this to the above results when the 3D object was small the accuracy was not good and resulted to have a higher angle. With regards to labelling position Tatzgern et al. (2014) discuss how the spherical object most anchor points is based on one side. The anchor points is referring to the labels and they are placed mainly in the face. This suffers from stacking of annotations rather having long poles which form the arrow of the label. In relation to this study the user is unbound where to place the label on the 3D object. If the labels look stacked the user can always rotate the arrow and move the label further to the top.

In the next section the method how the labels are being saved and loaded from the cloud database using Firebase will be critically discussed.

4.1.4 Cloud Storage

In figure 4.7 one can view the data that is being saved from the app, which is going on cloud Firebase. A script was prepared during development, to enable the user wants to load labels from the cloud, in order to make reference from Firebase and get the children such as "ArrowPosX", "ArrowPosY" and save it in a list since it contains two parameters. The same method goes for the saving the labels. In figure 4.7 the "ArrowPosX","ArrowPosY","ArrowPosZ" represents the position of the arrow that is attached to the label. These three parameters go in a Vector 3. The "ArrowRotX","ArrowRotY","ArrowRotZ" and "ArrowRotW" represents the rotatioin of the arrow and these goes into a quaternion hence four parameters. "LabelPosX","LabelPosY","LabelPosZ" are the position of the label itself and "LabelRotX","LabelRotY","LabelRotZ","LabelRotW" are the rotation of the label. The "LabelScale" is the scale of the label i.e. how large is displayed the label on the screen. "Label Text" is the text inside the labels. "ObjectTarget" is the current object target that is detected and where the labels are created on.


```json
"Labels" : {
  "4EJaSd81efR94PESEQP7HURPKak2" : {
    "motor" : {
      "ArrowPosX" : [ 3.75600004196167, 3.75600004196167 ],
      "ArrowPosY" : [ -3.5510001182556152, -3.5510001182556152 ],
      "ArrowPosZ" : [ 0.2720000147819519, 0.2720000147819519 ],
      "ArrowRotW" : [ 0.9238089323043823, 0.9114683270454407 ],
      "ArrowRotX" : [ 0.2872554063796997, 0.3092392683029175 ],
      "ArrowRotY" : [ 0.13631634414196014, 0.12406154721975327 ],
      "ArrowRotZ" : [ -0.21325859427452087, -0.24125763773918152 ],
      "LabelPosX" : [ 0.06449691951274872, 0.0017868168652057648 ],
      "LabelPosY" : [ 0.11603884398937225, 0.0799359679222107 ],
      "LabelPosZ" : [ 0.069987952709198, 0.05373045802116394 ],
      "LabelRotW" : [ 0.948002278804779, 0.9418349266052246 ],
      "LabelRotX" : [ 0.30952104926109314, 0.32843104004859924 ],
      "LabelRotY" : [ 0.0727635845541954, 0.05615386366844177 ],
      "LabelRotZ" : [ -0.013923052698373795, -0.04389306530356407 ],
      "LabelScale" : 0.009999999776482582,
      "LabelText" : [ "tank", "silencer" ],
      "ObjectTarget" : "motor"
    }
  }
}
```


Figure 4.7: Cloud Storage data format.

Figure 4.8 demonstrates the data that is being saved from the application, which is going on the cloud Firebase. The car has two labels which are 'tire' and 'rim'. The others are the rotation and position of the label and the arrow attached to the label. The object target is the model that the AR label was created on which is the Porche 3D model.

MCAST


```json
{
    "Porche" : {
      "ArrowPosX" : [ 3.75600004196167, 3.75600004196167 ],
      "ArrowPosY" : [ -3.5510001182556152, 3.5510001182556152 ],
      "ArrowPosZ" : [ 0.2720000147819519, 0.2720000147819519 ],
      "ArrowRotW" : [ 0.9156149625778198, 0.9256149625778198 ],
      "ArrowRotX" : [ 0.3444504737854004, 0.3444504737854065 ],
      "ArrowRotY" : [ 0.052055664360523224, 0.052055664360523335 ],
      "ArrowRotZ" : [ -0.2007323056459427, 0.23073230564594216 ],
      "LabelPosX" : [ 0.13416555523872375, 0.13416555523874368 ],
      "LabelPosY" : [ 0.08628591895103455, 0.08628591848703455 ],
      "LabelPosZ" : [ 0.08062300086021423, 0.0806230008602112 ],
      "LabelRotW" : [ 0.9373540282249451, 0.1649230008602142 ],
      "LabelRotX" : [ 0.347688227891922, 0.2315490008602124 ],
      "LabelRotY" : [ -0.021652542054653168, 0.1515825390815735 ],
      "LabelRotZ" : [ -0.0034033372066915035, -0.0065421206691235415 ],
      "LabelScale" : 0.015336291864514351,
      "LabelText" : [ "tire", "rim" ],
      "ObjectTarget" : "Porche"
    }
}
```


Figure 4.8: Cloud Storage data format .

Figure 4.9 shows the data that is being saved from the application that is going on the cloud. When the user wants to load the labels again this information is transformed into labels. Previously, it was mentioned that a script was created to this functionality. The object target which is the motorbike 3D model has two labels created around it which are 'tire' and 'tank'.

```
{
   "Repsol" : {
     "ArrowPosX" : [ 3.75600004196167, 3.75600004196167 ],
     "ArrowPosY" : [ -3.5510001182556152, -3.5510001182556152 ],
     "ArrowPosZ" : [ 0.2720000147819519, 0.2720000147819519 ],
     "ArrowRotW" : [ 0.9238089323043823, 0.9114683270454407 ],
     "ArrowRotX" : [ 0.2872554063796997, 0.3092392683029175 ],
     "ArrowRotY" : [ 0.13631634414196014, 0.12406154721975327 ],
     "ArrowRotZ" : [ -0.21325859427452087, -0.24125763773918152 ],
     "LabelPosX" : [ 0.06449691951274872, 0.0017868168652057648 ],
     "LabelPosY" : [ 0.11603884398937225, 0.0799359679222107 ],
     "LabelPosZ" : [ 0.069987952709198, 0.05373045802116394 ],
     "LabelRotW" : [ 0.948002278804779, 0.9418349266052246 ],
     "LabelRotX" : [ 0.30952104926109314, 0.32843104004859924 ],
     "LabelRotY" : [ 0.0727635845541954, 0.05615386366844177 ],
     "LabelRotZ" : [ -0.013923052698373795, -0.04389306530356407 ],
     "LabelScale" : 0.009999999776482582,
     "LabelText" : [ "tank", "tire" ],
     "ObjectTarget" : "repsol"
   }
}
```


Figure 4.9: Cloud Storage data format.

4.1.5 Profiler

A profiler is a tool inside Unity which gives the result about different aspects of the application performance such as memory, rendering, CPU time and how frequently Physics calculations are being performed. The user mobile can be connected with a wire and to run the application. The results are then saved in an Excel format. Figure 4.10 shows that the present frame time is much faster than the render time. This is because the scene has a lot of textures and the performance is going to be heavy on the mobile phone so, this slows the render time of the smartphone.

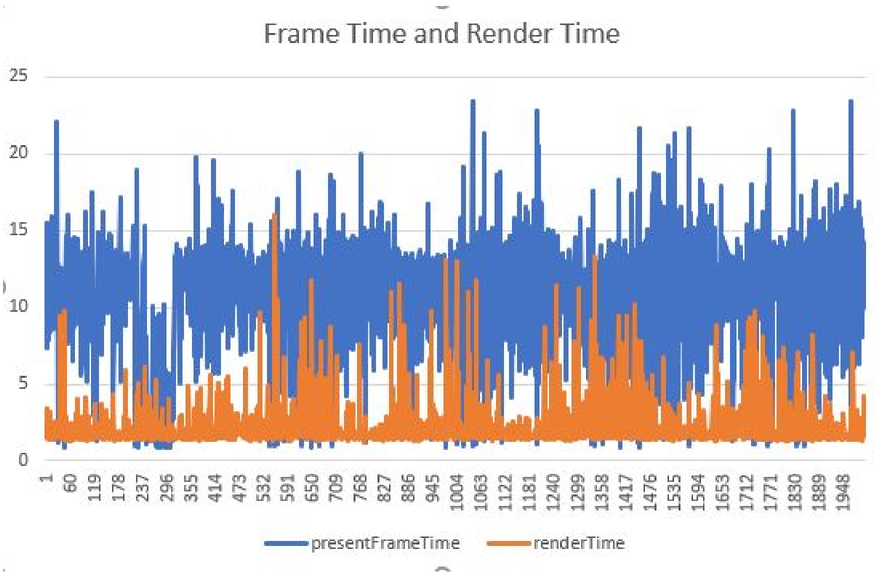


Figure 4.10: Profiler Rendering time.

Other studies

The detection of the 3D model was being lost quickly, even the labels. With regards to cloud database, Chatterjee et al. (2018) used Firebase to build a chat application between two users. This was deemed to be more efficient and a lot faster compared to traditional server-sided database using a scripting language. Compared with the above results using Firebase the application was working efficiently when loading the labels and it can be used by multiple users not only two, compared to the other study.

4.2 Discussion of overall results with other studies

Ang and Lim (2019) discussed uploading objects on Google cloud storage. A repository was created for each SceneForm asset file and these later will be downloaded later onto the mobile phone. Hence, the application will identify the object that needs to be displayed. To train the models MobileNets was used, because it features a small and efficient network design to efficiently maximize accuracy. The mobile device should be connected to the internet to download the 3D model and also for the application to fully utilize the functionalities. An other study by Paelke (2014) is using AR and sensors to determine the current position and orientation of the user in the real world. The sensors and AR correspond together using the software and these can be referred as tracking movement. The AR system determines which information is relevant and should be displayed in the user's current field of view. Finally, the information that is going to be displayed is a Video see-through, Optical see-through and Projection. In a study by Jayananda et al. (2018) for indoor-navigation Vuforia was used to store the images and object targets and SQLite as a database embedded with unity. These technologies enable the user to find a path in a supermarket. Google map API was used also to help navigation to the customer's doorstep with less time and in the easiest path. It was also found that GPS does not support indoor navigation. Hence to solve this issue WI-FI hotspots or Bluetooth beacons signals can be used. Finally, Sabarinathan et al. (2018) stated that using AR and machine learning can also display some text over a superimposed image using a smartphone camera. The text can be displayed on a 3D model in real time. The user also can see videos of the steps to perform maintenance operation. The video also can be paused if the machine under maintenance is away from focus. It also can be concluded that time for training can be reduced.

4.3 Qualitative Results and Analysis

In this section qualitative data will be presented, analysed and discussed in relation to the user's point of view and suggestions about the AR mobile application. For each result, a comparison with other studies is made.

4.3.1 Questionnaire Analysis and Discussion

The responses of the questionnaire are going to be introduced as theme such as method to learn, mobile application navigation, the likeliness of AR mobile application and AR mobile application. Moreover, the results visualisation are going to be represented as charts such as clustered bar chart, bar chart and pie chart and will be discussed. Thirteen respondent's took part in the questionnaire that was published through Microsoft Forms. To analyse the respondent's generic answers Google NLP API was used to derive insights form an unstructured text.

Method to learn

The below clustered bar chart shows that if the user preferred learning in a normal classroom since it can be used from everywhere at any time or instead use the more efficient way which is the AR mobile application. The other question was whether the user prefers using traditional resources like notes, presentations, or videos in order to learn or instead use the AR mobile application. The majority of the participants chose to choose the AR mobile application instead of learning in a normal classroom in a traditional manner. Since technology is evolving it is making the student's life easier to manage their studies in order to learn. When using the application, it can also be easier to share the work with the lecturer.

Mobile application Navigation

The below clustered bar chart shows how the user found the navigation of the mobile phone. The majority of the participants found it easy to use. It also shows how the user found the position and rotation of the label arrow. The majority of the participants determined that the app was also easy to use. This results that the participants already had an experience of using an AR mobile application and knew how to manage the use of a smartphone.

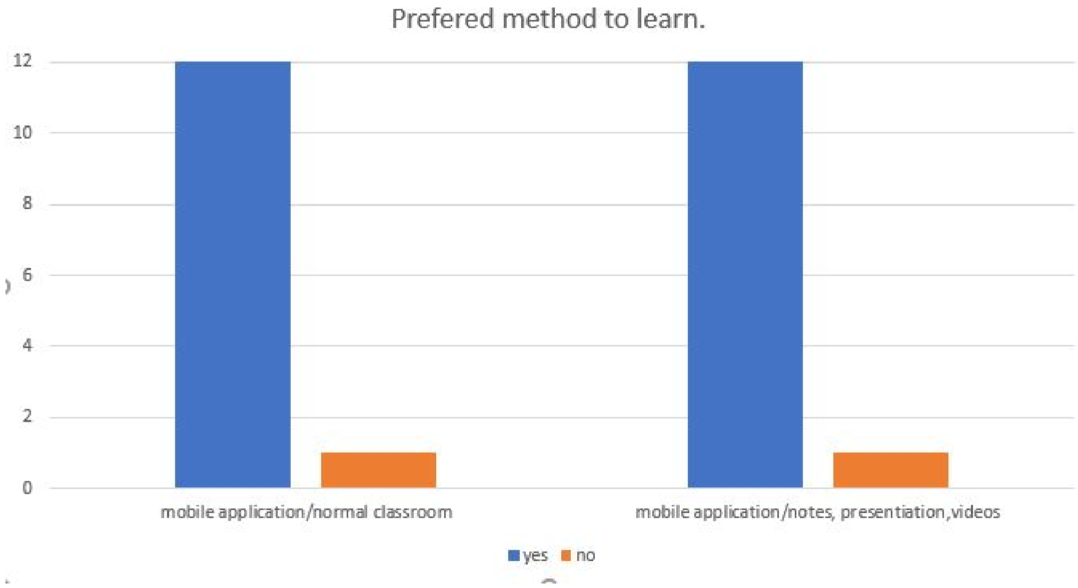


Figure 4.11: The User preferred method.

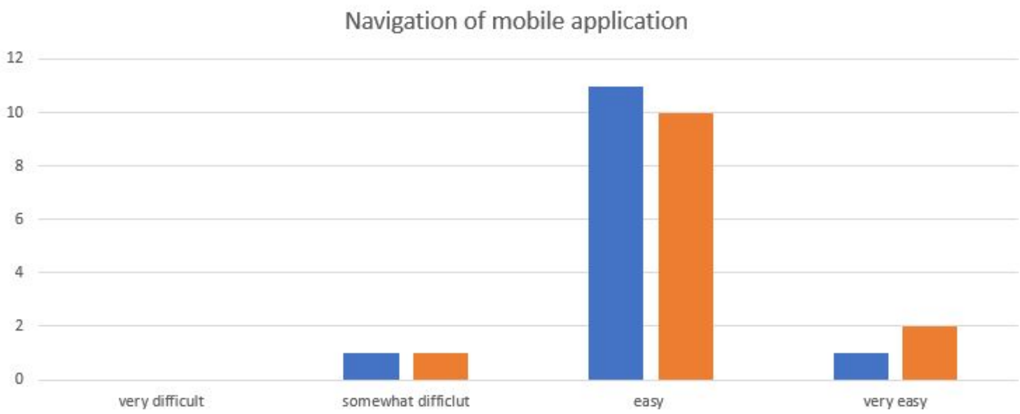


Figure 4.12: The navigation of AR mobile application and the position/ rotation of the label.

The likeliness of AR mobile application.

The above bar chart shows the user likeliness about the AR mobile application. Most of the participants expressed the fact that it is fun to use the application, whilst other participants said that it is easy of use to learn about the animal models. The AR mobile application was tested on different 3D animal models and the users had to create AR content such as labels and save them on the cloud. After doing so the participants determined that the application is quite fun to use.

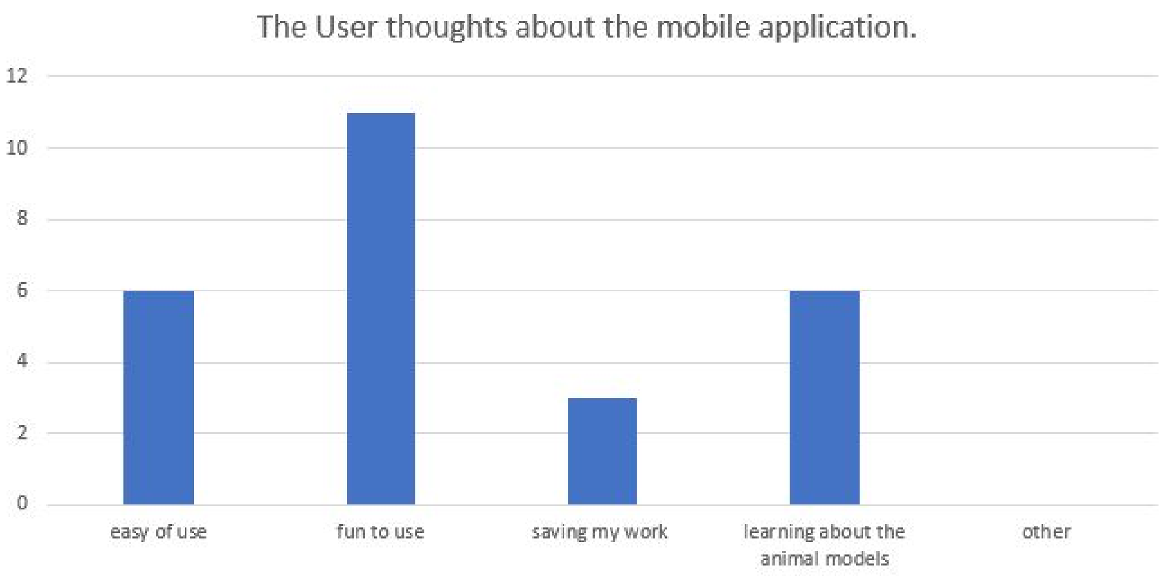


Figure 4.13: The likeliness of the user about the AR mobile application.

AR Mobile Application

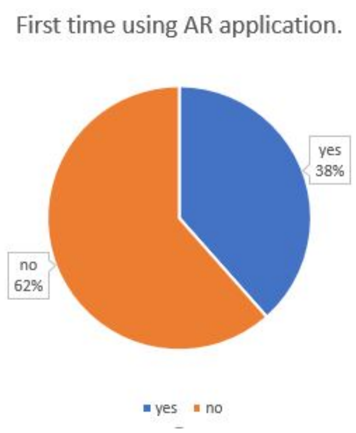


Figure 4.14: Using an AR mobile application

The above pie chart shows that 62% of the participants have not used an AR mobile application before doing this interview. On the other hand, 38% of the participants have used an AR mobile application. The participants that have used an AR application might have used the Pokémon Go application, Instagram or Snapchat, since these three are the most popular mobile application that use AR. The author however noticed that the other participants that stated they have never used an AR application might not have known that the applications are listed above use AR.

Improvements to the current existing features.

The most common answer to this question was about the User Interface and animal models. It was noticed that when loading labels from the cloud there is nothing demonstrating that the labels are being loaded. The UI has a menu on the left that includes buttons enabling the user to choose what function to select. Ultimately the user can scan models and input them manually. It was suggested to give a link to Wikipedia about the organs given. In the future depending on the animal model, an automatic link can be given to the user to access information about the model.

1	anonymous	More easy to load interface
2	anonymous	Have a more user friendly lay out with bigger buttons place at the top or bottom of the screen
3	anonymous	None
4	anonymous	Include some more animal models
5	anonymous	N/A
6	anonymous	Labeling
7	anonymous	nicer UI, more animal models
8	anonymous	saving locally as well since internet access might not be available in certain areas
9	anonymous	Loaing interface
10	anonymous	More details about the organs given. For example a link to wikipedia or something
11	anonymous	
12	anonymous	Different label suggestions if the user is stuck.
13	anonymous	None

Figure 4.15: Improvements to the existing features.

New features suggested by the participants

The most common answer was related to labels. One of the participants suggested to integrating AI in the mobile application. This can determine if the label is in the correct position when dragging the label in 3D place. This can be formed into a game, quiz or an assignment so points can be given to the student. Also, a suggestion button would be considered to provides hints to the student about the labels. Another participant suggested that the labels can be preset, so that the student can see the answers if he or she does not know the organs of the animal. This can be easily done, instead of loading the labels from the cloud or text file, the labels can be created on the 3D model by the developer.

1	anonymous	Not sure
2	anonymous	Having separate save files for labels on the same animal
3	anonymous	NA
4	anonymous	Highlighting certain parts
5	anonymous	the option to take a photo of the thing to be labelled
6	anonymous	Moving 3D objects
7	anonymous	drag and dropping animal organs in their correct position
8	anonymous	Suggested Labels on certain parts of an object by using AI
9	anonymous	Different models
10	anonymous	Other than animals, it could be used for plants
11	anonymous	
12	anonymous	Preset labels already complete.
13	anonymous	None

Figure 4.16: New features that can be included in the mobile application.

Achieving goals using the AR mobile application

The majority of the participants answered 'Yes'. The application can be used during a lecture one of the participants said, 'Yes' because it might give everyone the chance to answer the same question'. The application can be used by different participants and their work is going to be saved on the cloud, so this results in giving a chance to everyone to answer the same question. Another interesting answer is that the app helped the participant visualize what he/she is learning more easily. Since it is difficult to understand using a poster or a presentation, the mobile application intention is to practise more and participate during the lecture. Thus, if the student has a difficulty understanding something the lecturer can explain using the AR mobile application.

1	anonymous	Yes makes it easier for me
2	anonymous	Yes it does, allows me to customize the layout and position of the labels which allows me to make it more neat and less clustered
3	anonymous	Yes, excellent pedagogical tool to reach students better.
4	anonymous	Helps to identify the exact anatomical parts of the animals
5	anonymous	Yes because it might give everyone the chance to answer the same questions
6	anonymous	Yes
7	anonymous	yes it helps me visualize what i am learning more easily
8	anonymous	You can scan and label models anywhere and at any time with minimum effort
9	anonymous	Ease of use and interactivity
10	anonymous	It is highly educational
11	anonymous	
12	anonymous	Yes, it provides a different and interactive way of learning about animal anatomy
13	anonymous	Yes

Figure 4.17: With the existing features, does the mobile application help achieve your goals?

4.3.2 Other studies

Additionally, from the findings of Schiavi et al. (2018) it could be concluded that 46.2% of the students have never before experienced AR. In addition to this 75% of the participants felt better to have a better understanding using the augmented reality application than using traditional learning. Comparing to the above qualitative results 62% participants said they did not have an experience before they used the AR mobile application and this is much higher percentage compared with (Schiavi et al., 2018). Also, most of the participants from the qualitative results preferred to use the mobile application than the traditional way of learning. This can conclude that the mobile application is preferred as it can be used anywhere, rather than in a normal classroom.

Chapter 5

Conclusion

Following the above discussion, the below concluding summary outlines the main findings, relating them to the original hypothesis and research questions. Limitations of this study and suggestions for future research are discussed.

5.0.1 Main Findings

The main findings related to the qualitative research methods, namely the questionnaire following the pilot-test, was that the participants preferred to use the mobile application over traditional learning, as they found that it was more fun and easier to use the application and a suggestion was to improve the user interface. This observation addresses research question number one which sought to investigate the teaching and learning within a real classroom scenario. The main themes emerging were the ability of using the application anytime and anywhere, the students interacting more profoundly with the learning content during a lecture and students preferring the mobile application over traditional presentations and notes.

Another main finding related to the results of the cloud storage, an account can be created for individual users to create labels around a 3D model. This 3D model can be scanned using a simple 3D scanner app and can be uploaded on the target manager as a 3D point cloud. The user can also upload multiple 3D models. After this operation, the user can create AR content around the 3D model. Firebase was used as cloud database storage to save the labels information for each user so later these can be loaded. This solution was also used to give the app multi-user functionality, thus addressing research question number two, which sought to investigate the creation of a multi-user, cloud based and dynamic system adaptable for any object.

In response to research question number three, which sought to analyse accuracy and performance, quantitative tests were performed. When testing with medium 3D objects a high degree of accuracy was observed with content perfectly aligned with the medium 3D model. The performance of the AR mobile application was analysed using profiling tools were processing time was faster than the render time of the smartphone, signifying that no frames were dropped with the app working reliably even on entry-level devices.

5.0.2 Limitations

This study has several limitations. Firstly this is just a proof of concept, to prove a point that an AR mobile application can facilitate the teaching and learning. Although a lot of users from the questionnaire advised about the UI poor condition, that is taken into an account, however, this was beyond the purpose of the study. Due to Covid-19 restrictions the AR mobile application was tested in a classroom environment at the MCAST agribusiness institute with 5 participants. Precautions were taken such as using hand sanitizer before using an equipment and face masks were worn at all times. If there were no restrictions, the AR mobile application could have been tested by more people to gather more feedback.

The developed prototype is restricted to detecting one model at a time. This was done given the nature of the objects used in the pilot-study which encompassed the animal models. Users were advised to focus on one model at a time, so as not to misplace labels with the wrong object when pushing to the cloud database.

5.0.3 Recommendations for future research

This prototype can be further developed into an assessment tool, in the form of a test or quiz for the student to study and be examined. Integration of Facebook or Google Account to register within the mobile application using Firebase is also suggested. Scanning of larger models, such as large machines or a vehicle so that they can be labeled and studied by engineering students. While labelling the 3D models, information can be displayed on the 3D model so it can give some tips to the user. Virtual buttons can be used to rotate the arrow of the labels due to smaller screen of the smartphone it can be difficult sometimes to rotate and handle the arrow of the label. More researchers are developing mobile applications that assist lecturers in creating more content to teach the students, with students finding it easier to learn and study. Ferguson et al. (2015) mentions that lecturers can update the system for their own particular scenario. The lecturer can set up a number of questions for the students to make the entire learning procedure more effective. Further research can also be made to integrate AI with this application so it can detect if the labels around the 3D model is in the right position and correct text.

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