BACHELOR THESIS & COLLOQUIUM (ME184841)

THE DEVELOPMENT OF DIESEL ENGINE OPERATION TRAINING USING AUGMENTED REALITY APPLICATION

IVAN ADITYA NUGRAHA
NRP. 04211641000033

SUPERVISOR:
DR. ENG. TRIKA PITANA, S.T., M.SC.
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DOUBLE DEGREE PROGRAM
DEPARTMENT OF MARINE ENGINEERING
FACULTY OF MARINE TECHNOLOGY
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SKRIPSI – ME184841

PENGEMBANGAN ALAT PELATIHAN OPERASI MESIN DIESEL MENGGUNAKAN APLIKASI *AUGMENTED REALITY*

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2020

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APPROVAL FORM

THE DEVELOPMENT OF DIESEL ENGINE OPERATION TRAINING USING AUGMENTED REALITY APPLICATION

BACHELOR THESIS

Submitted to Comply One of the Requirements to Obtain
Bachelor Engineering Degree

on

Digital Marine Operational and Maintenance (DMOM) Laboratory
Bachelor Program Department of Marine Engineering
Faculty of Marine Technology
Sepuluh Nopember Institute of Technology

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Submitted in fulfilment of requirement for the degree of Bachelor Engineering

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Bachelor Program of Marine Engineering Faculty of Marine Technology

Sepuluh Nopember Institute of Technology

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SURABAYA

AGUSTUS, 2020

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DECLARATION OF HONOR

I hereby who signed below declare that:

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Name	: Ivan Aditya Nugraha
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Bachelor Thesis Title	: The Development of Diesel Engine Operation Training Using Augmented Reality Application
Department	: Marine Engineering

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Surabaya, August 2020

Ivan Aditya Nugraha

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THE DEVELOPMENT OF DIESEL ENGINE OPERATION TRAINING USING AUGMENTED REALITY APPLICATION

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ABSTRACT

In the last decade, Augmented Reality (AR) technology popularity increased on several areas of application, including the marine industry. Many companies nowadays seeking for a new ways to improve the operational efficiency and provide additional value to the customers. On the area of education, the augmented reality provide a significant benefits to transfer knowledge faster than the traditional methods, and help the companies to provide an effective training program for their employees. The diesel engine operation tasks are more challenging and need a disruptive technology to make the job easier. The Augmented Reality technology can help during the training process by giving step-by-step instructions to develop specific tasks. The information in AR application is rendered ubiquitously that will help the worker the ability to receive the instructions with less effort, understandable, and efficient which will avoid the faults in real diesel engine operation. The process starts by analysis of the current diesel engine components to identify how augmented reality technology can be implemented to improve the effectiveness of the process. Then, the diesel engine is rendered into 3D model including the proportional dimension and exact location of every diesel engine components as installed and the possible scenario that may happen in real condition. The 3D model is processed as an input for the augmented reality application using Unity3D software and assembled with other resources such as assets, scripts, texts, graphics, animation, sounds, and hardware in order to develop the augmented environment. The result of this research is called Diesel AR application. A testing process is done to determine whether the augmented reality application and preliminarily tested during the creation stage is ready for implementation. In the operation, the AR application is fully operated and tested by using android smartphone or tablet devices. A questionnaire is used to assess the feedback from the users of the AR application with specified parameters regarding the performance and the usefulness of the application. Based on the questionnaire result with the total score of 460, can be concluded that the Diesel AR application is categorized as Excellent performance. Therefore, the Diesel AR application is ready to be implemented into broader audiences and users.

Keywords*: Augmented Reality, 3D Modelling, Training Software, Diesel Engine Operation*

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PENGEMBANGAN ALAT PELATIHAN OPERASI MESIN DIESEL MENGGUNAKAN APLIKASI *AUGMENTED REALITY*

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ABSTRAK

Dalam dekade terakhir, popularitas teknologi Augmented Reality (AR) meningkat pada beberapa area aplikasi, termasuk industri kelautan. Banyak perusahaan saat ini mencari cara baru untuk meningkatkan efisiensi operasional dan memberikan nilai tambah kepada pelanggan. Di bidang pendidikan, augmented reality memberikan manfaat yang signifikan untuk mentransfer pengetahuan lebih cepat daripada metode tradisional, dan membantu perusahaan untuk menyediakan program pelatihan yang efektif bagi karyawan mereka. Tugas pengoperasian mesin diesel lebih menantang dan membutuhkan teknologi yang mengganggu untuk membuat pekerjaan lebih mudah. Teknologi Augmented Reality dapat membantu selama proses pelatihan dengan memberikan instruksi langkah-demi-langkah untuk mengembangkan tugas-tugas tertentu. Informasi dalam aplikasi AR diberikan di mana-mana yang akan membantu pekerja kemampuan untuk menerima instruksi dengan sedikit usaha, mudah dimengerti, dan efisien yang akan menghindari kesalahan dalam operasi mesin diesel nyata. Proses dimulai dengan analisis komponen mesin diesel saat ini untuk mengidentifikasi bagaimana teknologi augmented reality dapat diimplementasikan untuk meningkatkan efektivitas proses. Kemudian, mesin diesel diterjemahkan ke dalam model 3D termasuk dimensi proporsional dan lokasi yang tepat dari setiap komponen mesin diesel yang dipasang dan skenario yang mungkin terjadi dalam kondisi nyata. Model 3D diproses sebagai input untuk aplikasi augmented reality menggunakan perangkat lunak Unity3D dan dirakit dengan sumber daya lain seperti aset, skrip, teks, grafik, animasi, suara, dan perangkat keras untuk mengembangkan lingkungan yang diperbesar. Hasil penelitian ini disebut aplikasi Diesel AR. Proses pengujian dilakukan untuk menentukan apakah aplikasi augmented reality dan diuji awal selama tahap pembuatan siap untuk implementasi. Dalam operasi, aplikasi AR sepenuhnya dioperasikan dan diuji dengan menggunakan perangkat smartphone atau tablet android. Kuisioner digunakan untuk menilai umpan balik dari pengguna aplikasi AR dengan parameter yang ditentukan mengenai kinerja dan kegunaan aplikasi. Berdasarkan hasil kuesioner dengan skor total 460, dapat disimpulkan bahwa aplikasi Diesel AR dikategorikan sebagai *excellent performance*. Maka, aplikasi Diesel AR siap untuk diimplementasikan ke khalayak dan pengguna yang lebih luas.

Kata kunci*: Augmented Reality, Teknologi, Perangkat Lunak Pelatihan, Pengoperasian Mesin Diesel*

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PREFACE

All the gratitude towards Almighty Allah for all the blessings and gifts so that the author can complete bachelor thesis with title of "The Development of Diesel Engine Operation Training Using Augmented Reality Application" in order to fulfil the requirements to obtain the bachelor degree program at Marine Engineering Department, Faculty of Marine Technology, Sepuluh Nopember Institute of Technology, Surabaya.

During the accomplishment of this bachelor thesis, author want to thank every parties that involved, helped, assisted, and supported the author so that the author is able to complete this very well. All thanks are delivered to:

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7. And other parties whom author can't mention all but very meaningful for author.

As an author, I realized there were some shortcomings in the preparation of this thesis. But I hope this work can be useful for further research. I feel honored for this opportunity. Any criticisms and suggestions that are built from the readers will be very expected. Finally, thank you for being our readers and I hope you enjoy reading this bachelor thesis.

Surabaya, August 2020

Author

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CHAPTER I
INTRODUCTION

1.1 Background

The industrial revolution starts to get the next step affecting several industries including the marine industry. Marine company experience huge demand for optimisation than ever before. Many companies seek for new innovation to increase efficiencies, lower operating costs, and extend their services at the same time. A critical investigation towards the technological field need to be conducted in order to determine what technologies are available that could bring benefits to the marine industry (Jacobs, Webber-Youngman, & Wyk, 2016). But in fact, nowadays, many company still rely on a traditional operation instruction manual for their employees that expresses information by using text, pictures, and forms. When the operator uses the instruction manual to perform the operation, the information on the paper needs to be converted into information that is understandable for the operator to carry out the process. This conversion process usually take much time and each person has different interpretations of the information that affecting the operation quality (LI, 2019).

The marine industry mainly focused to provide integral solutions for delivering fully operational vessels together with their life-cycle maintenance. The marine industry comprises several types of operation areas such as design and construction of vessels, development of naval navigation systems, overhauls of vessels, ships repairs, and diesel engine maintenance. From all of those areas, most companies are concerning to the Industry 4.0 concept to their operation in order to increase their efficiencies. Many companies seeking to apply the newest technologies related to ubiquitous sensing, Internet of Things (IoT), robotics, Cyber-Physical Systems (CPS), 3D printing or Big Data to provide better operational processes (Lamas, 2018). The operation process has a significant influence in the pricing of products or services offered by the company and represent a majority of the costs. Therefore, the planning of operation process is an important factor that need to be prepared well. In the early phase of the process, changes can easily be considered, but often faults are going to be recognized only during the execution of the operation process which is very costly and difficult to correct. These problems comes from inadequate training or insufficient human involvement, especially in times of shorter development times, rising demand for flexibility and increasing in product complexity. With the help of advanced guiding and training by Augmented Reality (AR) application, failures can be avoided and already rectified in the early stage of the operation planning process (Neb & Strieg, 2018).

In the last decade, Augmented Reality (AR) technology popularity increased on several areas of application. Many companies nowadays seeking for a new ways to improve additional value to the customer and produce a competitive advantage from their competitor. On the area of education, the augmented reality provide a significant benefits to transfer knowledge faster than the traditional methods, and help the companies to provide an effective training program for their employees (Ramirez, Mendivil, Flores, &

Gonzalez, 2013). The operation is one of the most important activities to improve the profitability and competitiveness of a company. Nowadays, operation tasks are more challenging and need a disruptive technology to make the job easier. One of the problem is that the expert training is difficult and operator usually requires months or even years to build enough knowledge in operation and they only refer to manual book and highly complex procedures. A promising solution, proposed a few years ago to assist the operation by Augmented Reality (AR) technology. Augmented Technology create and provide virtual information of the real condition in real time, therefore it make the understanding of the problem, the localization of specific components, and operation a lot easier (Fiorentino, 2013).

Augmented Reality research on system operation show promising results in increasing human performance and ability to execute technical operation tasks, improving the efficiency of operation administration and supporting the management decision making (Palmarini, 2017). Even though what mentioned above and AR technology being around for more than 50 years, there are still limited examples of its actual implementation in industry. For this reason, this research aims to present the concrete implementation of augmented reality in terms of technology used, applications, and limitation focusing on the diesel engine operation training. This research is organized in five sections. Section 1 provides introduction to present the necessary background or context for the research problem as well as the objectives, limitations, and benefits of the research. Section 2 consists of literature review which gives an account of relevant previous studies as well as knowledge foundation related to the topic of this research. Section 3 is the methodology utilised for the AR application development. Section 4 provides the main results of the AR application development. Finally, section 5 reports conclusions and recommendations for future works.

1.2 Statement of Problems

According to the information provided in the background section, this research attempts to:

a) How to implement augmented reality technology to develop diesel engine operation training?
b) How to model the real condition of diesel engine components into 3D modelling and install it into an augmented reality application?
c) How to adjust the proportional dimension of diesel engine components into augmented reality application?
d) How to determine the compatibility of augmented reality applications with user devices?
e) How to develop a user-friendly augmented reality application?

1.3 Research Limitations

In order to clarify the topic and make the problem more specific, the scope and limitation of research are defined as follows:

a) The scope of research is limited to the diesel engine components, diesel engine operation, 3D modelling, and augmented reality technology.
b) There is no accentuation on the actual data processing that is related with the diesel engine operation, henceforth no detailed explanation of the technical calculation processing functions.
c) The augmented reality application is only developed for main components of diesel engine.

1.4 Research Objectives

Following the background information and statement of problem mentioned above, this research has the following objectives:

a) To implement augmented reality technology for diesel engine operation training.
b) To model the real condition of diesel engine into 3D modelling and install it into an augmented reality application.
c) To adjust the proportional dimension of diesel engine components into augmented reality application.
d) To determine the compatibility of augmented reality application with user devices.
e) To develop a user-friendly augmented reality application.

1.5 Research Benefits

The benefits could be obtained from this research are to inform to the various organizations to the key features and the potential use-cases of augmented reality technology to provide an effective training program for the employees.

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CHAPTER II
LITERATURE STUDY

2.1 Problem Overview

Diesel engine operation is a vital aspect during the operation of the ship. The operator/crews onboard should responsible to handle any condition that might happen during the operation. In case of there is a problem with the diesel engine, the crew should able to perform repair activities properly. Wrong decision can lead to serious damage to the engine. But the faults are only can be recognized during the real execution of the operation process. The faults usually comes from inadequate training or insufficient human resources. Therefore, the crew should be prepared before placed onboard in order to provide an introduction or procedures for the operation. But, in fact, nowadays many companies only rely on traditional training program using textual instruction manual that difficult to understand and cannot represent the crew to the real condition. A promising solution, proposed a few years ago to assist the operation by Augmented Reality (AR) technology.

The augmented reality technology provides a significant potentials usage for diesel engine training. It enables the digital disruption for the industrial application to create a permanent process acceleration or digitalized process monitoring in real time. There are two kinds of processes that AR technology might give a significant benefits which is industrial processes and learning processes. In industrial processes, the AR technology provide a better approach to improve the efficiency of the processes by augmenting along the entire industrial processes with an on-demand location independent information. In the learning processes, AR technology represent an innovative learning media that brings a new way of learning experiences and learning scenarios due to the technological possibilities. The implementation of AR technology in diesel engine training might give the following benefits:

Table 2.1 Benefits of AR Technology in Training Program

Training of Workflow	Training of Decision Making	Training of Problem Solving
- Ability to operate the diesel engine and carry out processes - Shorter lead time of classical training - Step by step training of the workflow activities	- Gaining additional knowledge about the process - Knowing the impact of own activities	- Increasing the ability of solving standard errors - Understand quality factors - Improve preventive work awareness

By implementing AR technology, it can provide a location-independent training to the individual with no longer necessary to train directly to the workplace where usually costly errors can occurs. It makes senses to train the employees in a protected learning environment such as a seminar room or a learning factory but still get the same experiences as the real operation by using 3D objects. The training program can deliver step-by-step to a work process without causing serious damage.

2.2 Diesel Engine

2.2.1 Definition

Diesel engine is categorized as internal combustion engine that discovered by an engineer called Rudolf Diesel on February 27, 1892 with the imperial Patent office in Berlin for a "new rational heat engine" (Mollenhauer & Schreiner, 2010). The diesel engine works by performing combustion to the fuel to generate power. The diesel engine has been the best choice engine especially for heavy duty application in several industries for more than 50 years. It's popularity generated by the ability of the diesel engine itself which give a significant benefits to the users such as high durability, high torque capacity, and better fuel efficiency than other types of engines (Gerpen, 2010).

Figure 2.1 Marine Diesel Engine
Source: (Wärtsilä, 2019)

The diesel engine was used primarily in stationary and ship propulsion applications in the form of relatively low speed four-stroke normally aspirated engines. Since the 1939, every major industrial country has developed its own range of diesel engines. Its greatest market penetration has undoubtedly occurred in the field of heavy road transport where, it is now dominant. It is particularly in this field where development, in the direction of turbocharging in its various forms, has been rapid during the last twenty years, and where much of the current research and development effort is concentrated. However, a continuous process of uprating and refinement has been applied in all its fields of application, from the very largest low speed marine two-stroke engines, through medium speed stationary engines to small single cylinder engines for operation in remote areas with minimum attendance. There is little doubt that it will continue to occupy a leading position in the spectrum of reciprocating prime movers, so long as fossil fuels continue to be available and, provided it can be made less sensitive to fuel quality, well into the era of synthetic or coal derived fuels (Challen & Baranescu, 1999).

2.2.2 Diesel Engine Classifications

The fundamental classification of diesel engines can be determined based on the combustion system, there are two-stroke diesel engines and four-stroke diesel engines.

2.2.2.1 Two-Stroke Diesel Engine

The two stroke diesel engine was invented by Huga Güldner in 1899. This type of engine has a simpler mechanically than four-stroke diesel engines, but more advanced in thermodynamic and aerodynamic aspects. The two stroke diesel engine achieve the power stroke only in one revolution, 360 mechanical degrees. In a two-stroke diesel engine, more than one process occurs at any given time during the revolution of the engine processes (Walshaw, 1953).

In two-stroke engines combustion occurs in the region of top dead centre (TDC) of every revolution. Consequently gas exchange also has to be effected once per revolution in the region of bottom dead centre (BCD) and with minimum loss of expansion work of the cylinder gases following combustion. This implies that escape of gas from the cylinder to exhaust and charging with fresh air from the inlet manifold must occur under the most favourable possible flow conditions over the shortest possible period. In practice the gas exchange or scavenging process in two-stroke engines occupies between 100° and 150° of crank angle (CA) disposed approximately symmetrically about BDC (Challen & Baranescu, 1999).

2.2.2.2 Four-Stroke Diesel Engine

The four-stroke diesel engine is an internal combustion (IC) engine in which the piston completes the power generation process in four separate stroke while turning its crankshaft. It means, this engine achieve the power stroke by two revolution of the crankshaft, or 720 mechanical degrees. The stroke means the full movement of the piston along the cylinder, in either direction.

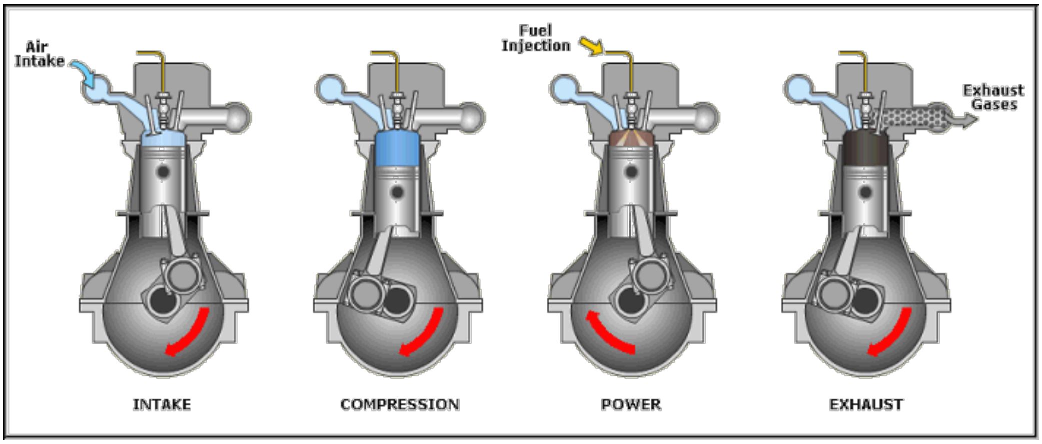

Figure 2.2 Four-Stroke Diesel Engine
Source: (Wärtsilä, 2019)

The majority of current diesel engine application in the industry operate on the four-stroke diesel engine. The combustion occurs only every other revolution, again in the region of top dead centre (TDC), and with the intermediate revolution and its associated piston strokes given over to the gas exchange process. In practice the exhaust valve(s) open well before bottom dead centre (BDC) following the expansion stroke and only close well after the following top dead centre (TDC) position is reached. The inlet valve(s) open before this latter TDC, giving a period of overlap between inlet valve opening and exhaust valve closing during which the comparatively small clearance volume is scavenged of most of the remaining products of combustion. Following completion of the inlet stroke, the inlet valves close well after the following bottom dead centre (BDC), after which the 'closed' portion of the cycle, such as the sequence compression, combustion, expansion, leads to the next cycle, commencing again with exhaust valve opening (Challen & Baranescu, 1999). The main advantages of the four-stroke diesel engine over the two-stroke counterpart are:

a) The longer period available for the gas exchange process and the separation of the exhaust and inlet periods apart from the comparatively short overlap resulting in a purer trapped charge.
b) The lower thermal loading associated with engines in which pistons, cylinder heads and liners are exposed to the most severe pressures and temperatures associated with combustion only every other revolution.
c) Easier lubrication conditions for pistons, rings and liners due to the absence of ports, and the idle stroke renewing liner lubrication and giving inertia lift off to rings and small and large end bearings.

These factors make it possible for the four-stroke engine to achieve output levels of the order of 75% of equivalent two-stroke engines. Considering these advantages and the most common diesel engine in the industry, the four-stroke diesel engine will be used as an object in this research to develop training program using augmented reality application.

2.2.3 Main Components of Diesel Engine

In order to understand the working principle of diesel engine, an understanding of the main components inside the diesel engine and how they work together is necessary. The diesel engine consists of the following main components (Gedeon, 2019) :

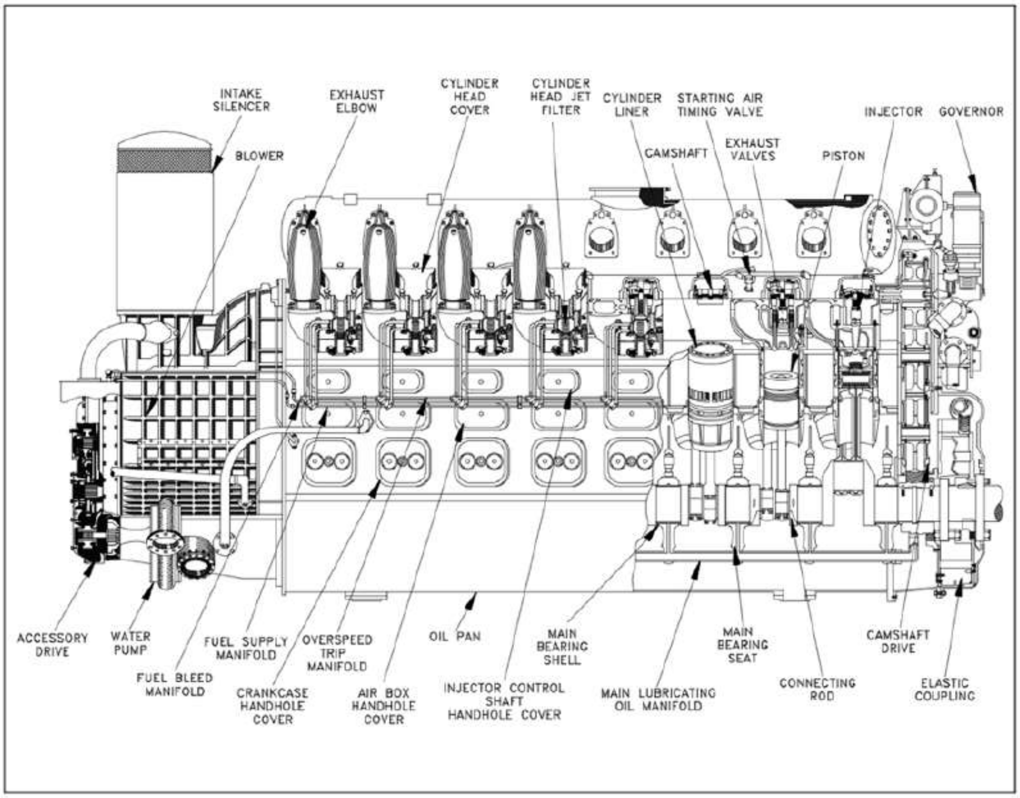

Figure 2.3 Cutaway of Four Stroke Diesel Engine
Source: (Gedeon, 2019)

2.2.3.1 The Cylinder Block

The cylinder block is a basic component of diesel engine which is generally a single unit structure made from cast iron. The cylinder block has a function to provides a rigid body to the structure and the frame of the diesel engine's cylinders, water coolant, and oil passages. It also used to support the crankshaft and camshaft bearings.

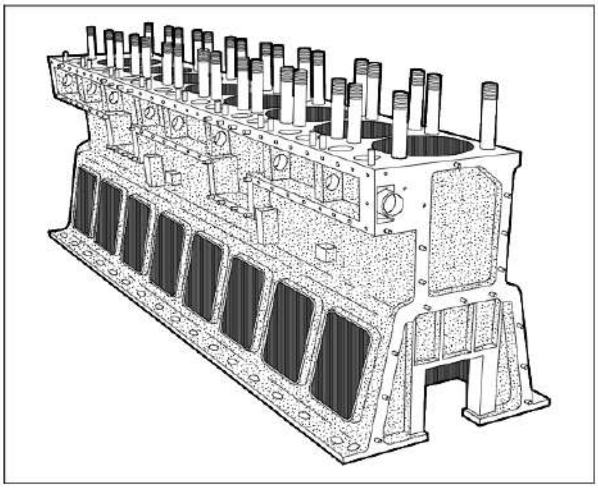

Figure 2.4 Diesel Engine Cylinder Block
Source: (Gedeon, 2019)

2.2.3.2 Piston and Piston Rings

Piston is one of the most important components in diesel engines. The piston makes the diesel engine able to transform the heat energy generated by combustion process into mechanical energy by utilizing the expanding gases that moves the piston upward and downward. The pistons are commonly made of aluminum or cast-iron alloys.

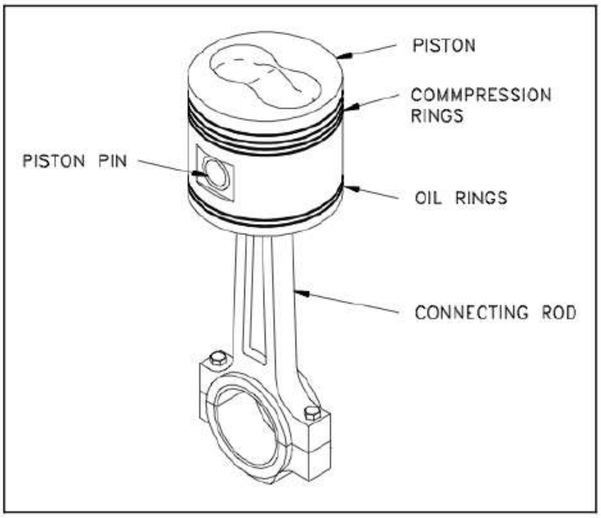

Figure 2.5 Diesel Engine Piston
Source: (Gedeon, 2019)

There is a piston rings which is located around the piston head and have function to prevent the combustion gases flow through the piston sides and to prevent high friction between the piston head with the cylinder wall. Each piston has several metal rings around it. The rings are usually made of cast iron and coated with chrome or molybdenum. Diesel engine pistons commonly have several rings around it, usually 2 to 5 units, with each rings perform a different function. The top rings perform as the pressure seal. The intermediate rings perform as the wiper to remove and control the amount of oil on the cylinder walls. The bottom rings perform as an oiler ring which ensures the lubricating oil is supplied and evenly deposited on the cylinder walls.

2.2.3.3 Crankshaft

The crankshaft is diesel engine component that have function to converts the linear motion generated by the pistons into a rotational motion that will be transmitted to the load. Crankshaft are usually made from forged steel. The crankshaft working together with the bearing and connecting road. The rod bearing are offset from the center of the crankshaft. This offset creates the reciprocating (up and down) motion generated from the piston into a rotary motion of the crankshaft. The amount of offset determine the stroke of the diesel engine.

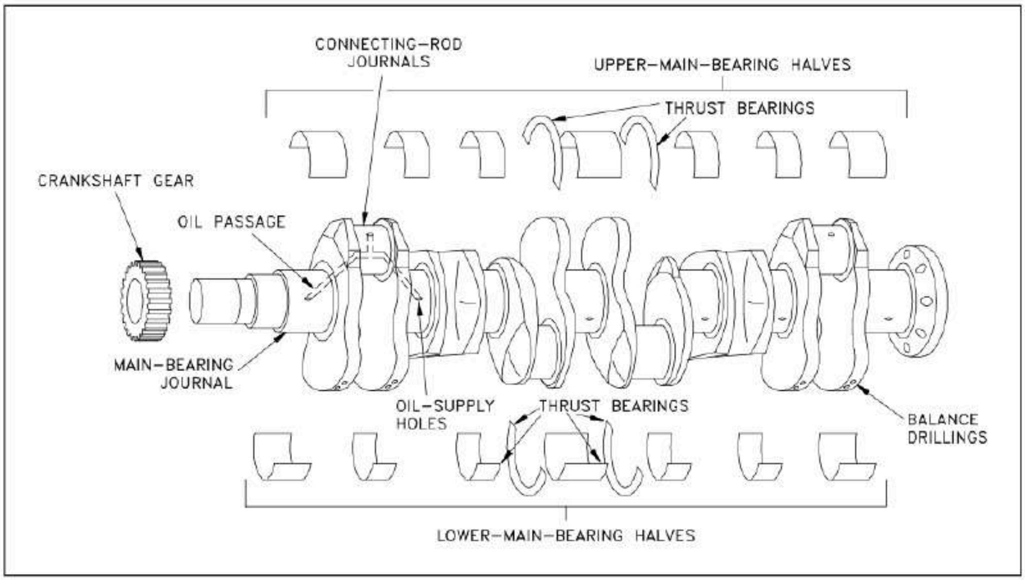

Figure 2.6 Diesel Engine Crankshaft and Bearings
Source: (Gedeon, 2019)

The crankshaft does not move directly on the cast iron block crankshaft supports, but it moves on special bearing material. The bearing material is a soft alloy of metals that gives a replaceable wear surface and prevents galling between two similar metals. The crankshaft is also drilled with oil passages that is used to maintain the movement.

2.2.3.4 Crankcase and Oil Pan

Crankcase is a diesel engine components that is used to supports the crankshaft and crankshaft bearings. The crankcase usually located on the bottom of the cylinder block. The crankcase area encompass the rotating crankshaft and crankshaft counter weights which will return the oil into the oil pan. The oil pan is located at the bottom of the crankcase. It is used to collects and store the diesel engine lubricating oil.

2.2.3.5 Connecting Rod

The connecting rod is a diesel engine component that have a direct relation with the piston and crankshaft. This component is used to connect the piston to the crankshaft. The connecting rods should provide a sufficient strength in order to transform the force from the piston to the crankshaft, and it is made from drop-forged, heat-treated steel to provide the required strength. The rods are required to transmit the compressive and tensile forces from the piston, and rotate at both ends in the crankshaft.

2.2.3.6 Cylinder Bore

The cylinder bore is a diesel engine components that provide the engine with the cylindrical structure needed to accommodate the piston movement to perform a combustion process. There are two types of diesel engine cylinder bore. The first one is each cylinder is machined and bored into the cylinder block casting that makes the block and the cylinders an integral form. The second type, the cylinders formed from a machined steel sleeve that is pressed into the block casting.

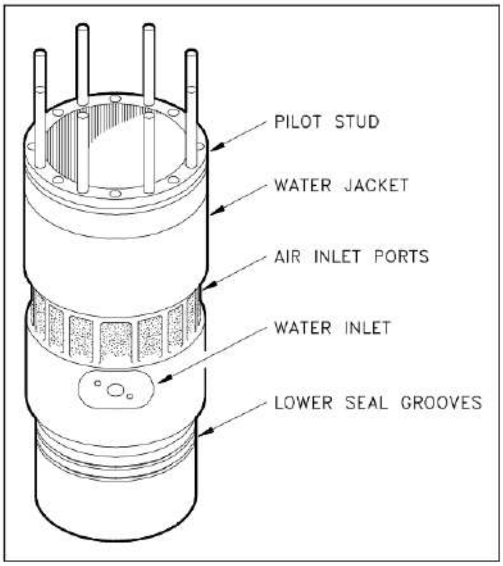

Figure 2.7 Diesel Engine Cylinder Bore
Source: (Gedeon, 2019)

2.2.3.7 Cylinder Heads and Valves

On the top of the cylinder bore, there are components called cylinder heads. These components have function to provide the top seal of the cylinder bore as well as provide the support for other additional components needed for the combustion process such as valves, fuel injectors, and necessary linkages.

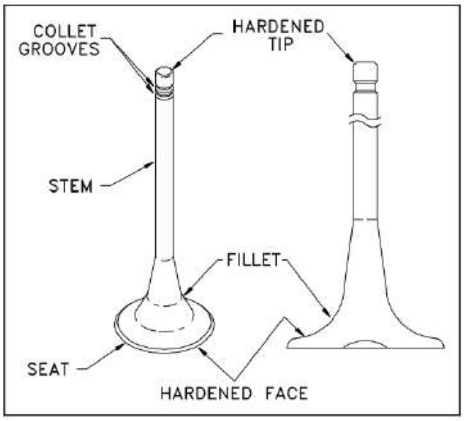

Figure 2.8 Diesel Engine Valves
Source: (Gedeon, 2019)

There are other components that attached on the cylinder heads which is used to perform the combustion process. The combustion process needs an air intake and exhaust gases exit. It can use either ports or valves or a combination of both. Ports are some kinds of slots which is located in the lower 1/3 of the cylinder bore. The ports are opened when the piston come through below the level of the ports, and the fresh air or exhaust gases are able to enter or leave the ports. Then, the ports closed then the piston travels back above the level of the ports. In other hand, valves are mechanically opened and closed to inject fresh air or exhaust gasses. The valves are located in the cylinder head casting of the engine.

2.2.3.8 Flywheel

The flywheel is a diesel engine components that have several function. The first, it is used to reduces the vibration generated by the combustion process by smoothing out the power stroke as each cylinder fires. The second, it is acting as the mounting surface used to bolt the engine with the load where the power of the engine will be delivered. And the third function, on some diesel engine manufacturer, the flywheel has gear teeth around its perimeter that allow the starting motors to engage and crank the diesel engine to starts. The flywheel is located on one end of the crankshaft.

2.3 Augmented Reality Technology

2.3.1 Definition

Augmented Reality (AR) can be defined as an emerging human computer interaction (HCI) technology that renders virtual information on a real scene. In other words, AR system is a real time and interactive application that able to blend real condition with virtual content in real environment (Azuma, 1997). The real world environment rendered in a real time direct or indirect view of physical body that has been enhanced/augmented by adding virtual computer generated objects/information to the environment.

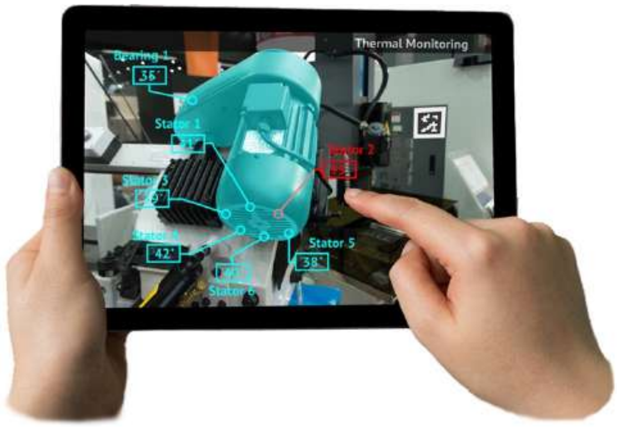

Figure 2.9 Augmented Reality (AR) Technology Overview
Source: www.autoexpose.org

Augmented Reality aims to simplify the life of the user by providing virtual information not only to the immediate surroundings, but also to any indirect view of the real world environment. This technology improve the user's point of view and interaction with the real world. There is a confusion between two emerging technology, which is augmented reality (AR) and virtual reality (VR). VR technology completely brings users in a virtual world without seeing the real world, while AR technology augments the sense of reality by providing virtual objects upon the real world in real time. Milgram's Reality-Virtuality Continuum defined by Paul Milgram and Fumio Kishino is a continuum that spans between the real environment and the virtual environment comprise Augmented Reality and Augmented Virtuality (AV) in between, where AR is closer to the real world and AV is closer to a pure virtual environment (Azuma R. , 2001).

AR technology can be potentially applied to all types of senses such as smell, touch, as well as hearing. Those kinds of features enabled to provide the users with the real experiences while using the AR application. The virtual objects that added to the real world shows the required information to the users, but the users cannot directly detect with their senses. The information provided in the AR application can be used to help the users to perform daily operation tasks (Carmigniani, 2010).

The augmented reality technology defined as human-machine interaction tool that overlays virtual computer generated information on the real world environment in real time, and it provide three key features that will help to improve training process in diesel engine operation, namely:

- Combining real and virtual objects in a real environment.
- Real time interaction between the user with the system, and able to receive the user's inputs.
- Geometrical alignment of virtual objects to real ones in the real world.

This technology also brings several strengths that can be beneficial to improve the effectiveness of the training process:

- Information are directly integrated in the real world in real time.
- The provided information are easily understandable by the user and it will give better understanding to the users.
- Paperless ability to provide a large amount of knowledge.
- Possibility of integrating the AR application system with other computer-aided devices.

2.3.2 Augmented Reality Framework

In order to develop AR application, need a good understanding of the technology behind. However, the most important aspects are the detailed scenarios, concept, and the contents of the AR application. Therefore, it is important to create an AR application framework prior the development processes. The framework defines clear understanding of the AR application structures to avoid missing assets or resources. The goal of the framework is to simplify and to speed up the development of AR application.

The framework of AR application can be separated into three areas, namely: picture taking, tracking, and graphic. An AR application needs a camera to picture the real world where the virtual objects will be located. After that, in order to recognize the objects, a tracking system must be performed to measure the position and orientation of the virtual camera. Both parameters is a basic important aspects of AR application which isolated from the user scenario. While the graphic part is dependent from the scenarios that is planned to visualize the received data and provide a virtual objects to give information to the users. These three areas are basic framework of AR application and should be implemented correctly to ensure the usability and maintainability of the application design (Kollatsch, 2014).

The presented framework enables the development of AR application should mainly focus on the scenarios and the graphical representation that will be delivered to the users. The creation of augmented objects should be managed properly to ensure that the users receive the exact same experiences while reacting the virtual objects with the real environments. The detailed overview of AR application framework shown in Figure 2.2 below.

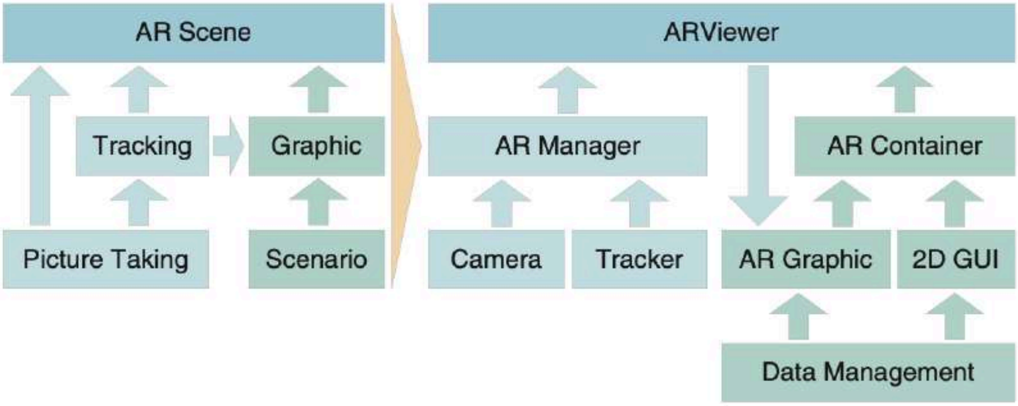

Figure 2.10 Structure of the Augmented Reality Framework
Source: (Kollatsch, 2014)

2.3.3 Types of Augmented Reality

The augmented reality concepts works by combining the virtual objects into real world to create a better experience. According to how the application overlays the virtual objects on the real world environments, there are two types of augmented reality (Camba & Contero, 2015):

2.3.3.1 Marker-Based Augmented Reality

Marker-based augmented reality utilize 2D images to recognize the three dimensional space seen by the camera and provide a correct position and orientation of virtual objects on the screen. This is the simplest type of augmented reality application where the users can use any type of 2D images to show the virtual contents inside the AR application. However, the 2D images should be registered to the application to be able to detect it.

The simplicity provided by this type of augmented reality, the marker can be easily integrated in anything, as long as it has a sufficient unique visual points. Typical examples of the marker include any print media such as logo, posters, brochures, packaging or even in a printed lecture notes and assignments, which allowing the instructor to enhance educational materials, and the students to visualize the contents being described on the paper in full 3D real objects.

The marker based augmented reality use the camera feature from the device to capture and analyse the marker that has been registered to the application and processing to display virtual objects related to the marker such as 3D images or video. Once the marker has been recognized and the virtual content is shown on the screen, the user can move the device to see the virtual objects at various different angles and sides.

Figure 2.11 Example of Marker-Based Augmented Reality
Source: (Camba & Contero, 2015)

2.3.3.2 Markerless Augmented Reality

Alternatively from the marker-based augmented reality, a regular image can provide a “markerless” interaction which use any image or even scan the real physical objects to trigger virtual AR content on the screen. This type of augmented reality is more ubiquitous and user friendly to be used in day to day operation. However, a high level of contrast and detail in the image, as well as mote processing power are required.

The markerless augmented reality eliminate the usage of marker or 2D image to display the virtual objects on the application. It recognize the real objects or real environment that has not been installed or registered to the application beforehand. This type of augmented reality is more difficult to develop because it requires a recognition algorithm installed in the AR application in order to identify the complex physical objects including the shapes, colors, patterns, and other important features that could exist in the camera frames during the operation of the AR application.

Figure 2.12 Example of Markerless Augmented Reality
Source: www.softmedialab.com

This research use the marker-based augmented reality to develop AR application content from 3D models of the diesel engine components generated through image-based modelling techniques and use 2D drawing of the diesel engine drawing to trigger the virtual objects in the AR application. Where, the marker-based AR provide the following advantages.

Table 2.2 Advantages and Disadvantages of Each Type of AR Technology

Type	Advantages	Disadvantages
Marker	• The most common type and easier to develop. • Relatively intermediate computer programming requirements. • Efficient tracking from the marker to trigger virtual objects faster.	• Intrusive and Invasive. • Marker similarity sensitive. • If part of the marker is covered, the virtual objects is lost.
Markerless	• Any image can be used as a marker • There are no intrusive markers which are not part of the environment. • Allow occlusion and virtual buttons.	• The image must have significant details and proper contrast. • More complex image tracking. • More hardware demanding. • The physical objects should exist in front of the camera.

2.3.4 Object Detection Method

The object detection in the marker-based augmented reality starts by acquiring an image captured from a camera and register the image into an inner representation within the AR application which is a kind of RGB color matrix. Then, the image will be analysed and identified to provide correct position and orientation of the possible wanted objects that has been registered in the application. The possible wanted objects will be compared to the predefined pattern from the marker. If the detection process is succeed, the last step is the insertion of the virtual objects. The complete process of object detection method in marker-based augmented reality shown in figure below (Procházka & Koubek, 2010).

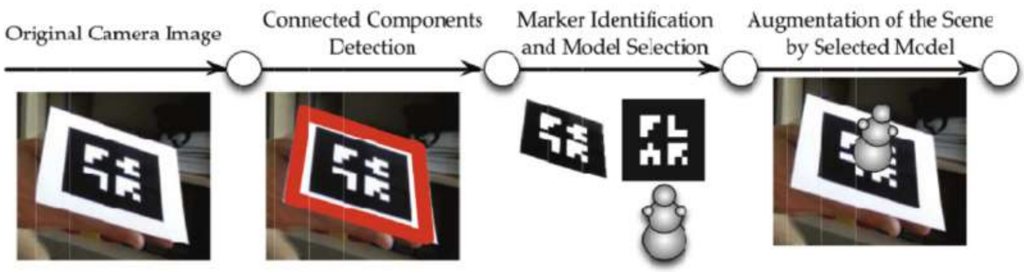

Figure 2.13 Structure of the Augmented Reality Framework
Source: (Procházka & Koubek, 2010)

This type of object detection method is quite common for all AR application. In this research, this object detection method will be used to detect 2D drawing of diesel engine as the marker and show the virtual objects on the screen simultaneously. This method is quite simple and could be used to develop basic AR application.

2.3.5 Main Augmented Reality Components

2.3.5.1 Hardware Devices

The reality world can be augmented in many different ways. The visual augmentation can be divided into three main categories. The first one is using the head mounted displays, the second one is using projectors, and the third one is using common displays devices (tablets, cell phones, etc) (Procházka & Koubek, 2010). However, the development and operation of AR application is not only on the display aspect, but it requires several additional resources in order to perform good interaction in the application. The main hardware components that needed to develop and operate AR application are (Dini, 2015):

a) Computer
The computer acts as the scene generator which is used to create the virtual contents and managing all the devices. It is needed to adjust the virtual content and the position of the user with respect to the scene, according to the information coming from the tracking system.

b) Display Device
This hardware is used to display the augmented visual content with the real world. It is also used to manage all the operation of the AR application according to the developed scenarios. There are three different categories of display devices, depending on the position of the user to the observed objects, namely:
- Head-Mounted Display (HMD), is a display device that worn on the user's head in order to operate the AR application. The head mounted displays are based on the optical composition of the scene or on the video composition. The optical composition is a projection of artificial objects on a semi-transparent screen before user eyes. The video composition combines an image from a camera with artificial objects and the result presents on a small LCD screen in a virtual helmet.
- Hand-Held Display (HHD), is a common display device that is portable and can be carried by hand such as tablets and smartphones which have additional necessary components such as: a suitable display, a high-resolution camera, a processor fast enough to make the real time image analysis and also a GPS accompanied by compass.
- Spatial Displays (SD), is the adaptive projector used for projection on heterogeneous surfaces. The projected image is controlled by the software and adjusted to compensate the differences between the anticipated and the real image.

c) Tracking System
The tracking system is used to obtain and record the user position and orientation with respect to the virtual objects shown on the screen, in order to provide a proper alignment of the virtual objects to the users and the real environment.

d) Interaction Tools
This hardware is tools that is used to create possibility of the user to interact directly with the virtual object or AR application in real time. The interaction tools can be a touchpads or wireless devices that act as additional input devices.

2.3.5.2 Software Development Tools for AR Application

In order to develop augmented reality application, it also need several software to combine and program all required resources into an AR application packages, namely:

a) Unity3D
Unity3D is a software that is developed by Danish Company Unity. It is a multi-platform virtual development tool. It categorized as fully integrated professional virtual engine and can provide such functions as rendering engine, physical engine, script engine, lighting mapping, and scene management. The Unity3D mainly used to creates interactive 3D and 2D application environment which can be used for training, simulation, and structural simulation (Li, Q, & Yu, 2010).

Figure 2.14 Unity3D Software Interface
Source: (Unity, 2019)

A package of Unity3D program is consists of several scenes, which each of the scene contains many models (virtual objects) and their behavior which is controlled by scripts (including JavaScript, C#, etc). The Unity3D is a common software to develop AR application due to its complete features (Li & Tang, 2019).

b) Vuforia SDK
Vuforia is a Qualcomm's software development kit for mobile AR applications, and it is an AR SDK for developers. It uses computer vision technology to identify and capture flat images or simple three-dimensional objects in real time, and allows developers to place virtual objects through camera viewfinders and adjust the position of objects in the physical background in front of the lens (Lu & Jin, 2017).

2.4 Augmented Reality for Industrial Applications

The increasing development of advanced application of augmented reality technology in Industrial systems caused by the increasing combination of latest advances technology in electronics, networking, sensors, and robotics, together with paradigms of Internet of Things (IoT). The industrial systems that may get benefits from those technology including energy efficiency, transportation, defense and public safety, automation, and security (Yan, Meng, & Li, 2017). Among those emerging technologies, Augmented Reality (AR) has proven to be the most suitable tool for the operational strategies proposed by different countries, which has the ability to enable the workers to collaborate among each other, interact with real-time information, and monitoring control systems efficiently (Drath & Horch, 2014). The figure below summarizes the most relevant industrial tasks and division where the augmented reality can bring value.

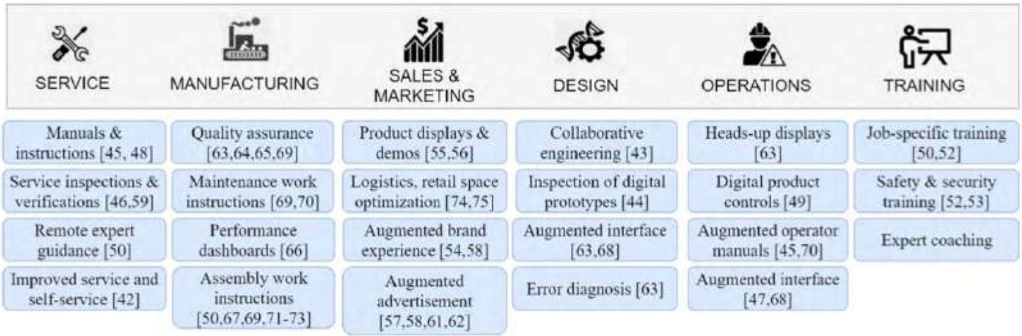

Figure 2.15 Augmented Reality Industrial Application
Source:
(Fraga-Lamas, Fernandez-Carames, Blanco-Novoa, & Vilar-Montesionos, 2017)

From all possible application of AR technology in several sectors within the industry, the most common application is the assistance to workers in operation/maintenance/repair/control tasks through instructions with visual, textual, and auditory information (Alesky, Vartiainen, Domova, & Naedele, 2014). The information contained in the AR application is rendered ubiquitously that will help the worker the ability to receive the instructions with less effort, understandable, and efficient which will avoid the faults in real life activities.

Another significant benefit for the AR application in the industrial process is enabling the remote assistance. The location-independent characteristic of AR technology provides a benefit when companies have machines installed in remote locations. The AR technology can help by easing remote collaboration between workers when the machines need to be operated, monitored, and maintained with the limited amount of people on-site (Smparounis, et al., 2008). The AR technology can help during the training process by giving step-by-step instructions to develop specific tasks. Especially useful for assembly in sequence which reduce time and effort of the workers. Well-trained operators are essential for productive company (Horejší, 2015).

2.5 Expected Result

The result of this research will be an augmented reality android application that can be installed on any android devices such as smartphones & tablets. The application will use the marker-based augmented reality. Each of the diesel engine main components will be rendered into 3D models. Inside the application, the diesel engine 3D models can be converted into exploded view that will showcase all the diesel engine main components. When the component is clicked, there will be an information about the component.

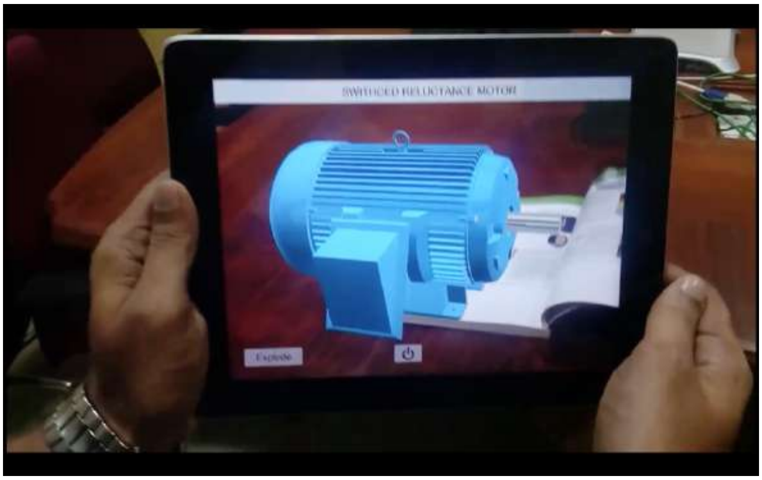

Figure 2.16 Complete View
Source: www.diacritech.com

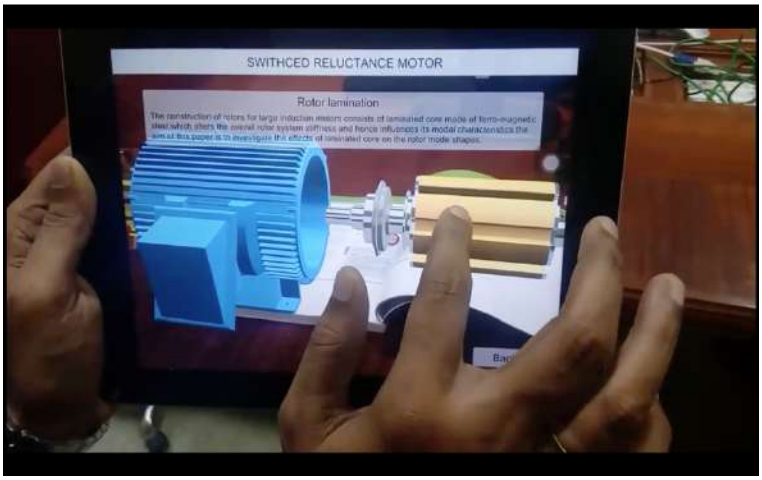

Figure 2.17 Exploded View
Source: www.diacritech.com

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CHAPTER III
METHODOLOGY

3.1 General Overview

In order to achieve the objectives, the remaining of this research is organized as follows:

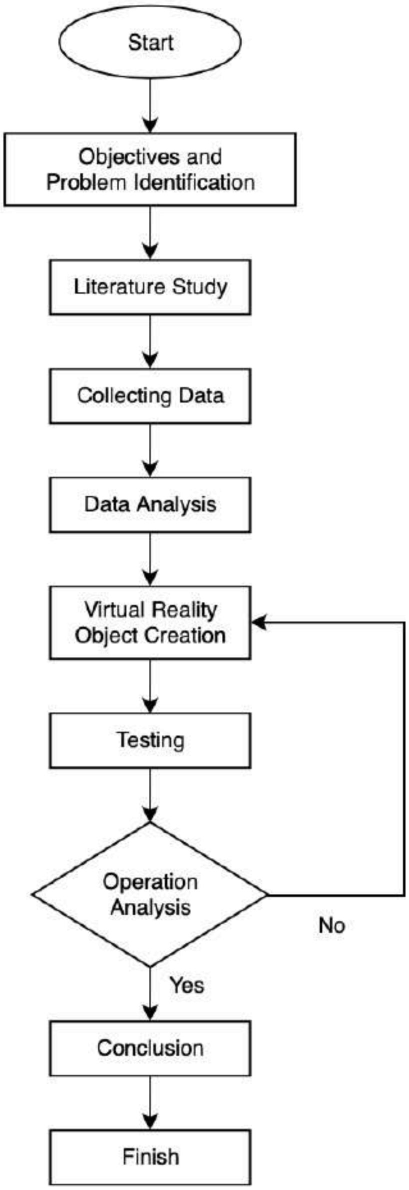

Figure 3.1 Research Flow Chart Diagram

3.2 Problem Identification

In this step provides introduction to present the necessary background or context for the research problem as well as the objectives, limitations, and benefits of the research.

3.3 Literature Study

In this section, the author provides the literature review, which gives an account of relevant previous studies as well as knowledge foundation related to the topic of this research. The literature study is carried out with various sources such as books, journals, articles, websites, and other publications related to diesel engine training and augmented reality technology.

3.4 Data Collection

Data collection will be carried out to obtain information about the data that needed to complete this research. There will be data gathering activity in which will be conducted from the diesel engine manufacturer project guide as the research object. The data that needed for this research are:

1. Lists of diesel engine components that should be installed.
2. The parameter to assess the condition of the diesel engine components.
3. The detail guidelines of diesel engine operation.
4. Visual and dimension record of each diesel engine components.

Data collection will be carried out by the diesel engine documentation from manufacturers and interviews with related stakeholders to find out in detail about the data needed for the research.

3.5 Data Analysis

In this step provides in depth analysis and discussion to answer the questions in statement of problems in this research by utilizing the data/information that have been collected. The data that has been collected will be used to define the augmented reality object creation. The analysis including the proportional dimension and exact location of every diesel engine components as installed and the possible scenario that may happen in real condition during the diesel engine operation with augmented reality application.

3.6 Augmented Reality Object Creation

At this stage, the development of augmented reality application begin. The first step is to create the 3D model of each diesel engine components using 3DS Max/Blender software with the dimension and location based on the data that has been collected. After that, the 3D model will be processed as an input for the augmented reality application using Unity3D software and will be assembled with other resources such as assets, scripts, texts, graphics, animation, sounds, and hardware in order to develop the augmented environment. The creation of augmented reality object should be conducted properly to ensure that the user of the augmented reality application have the same experience as the real condition during diesel engine operation.

3.7 Testing

In this testing stage, will be done to determine whether the augmented reality application and preliminarily tested during the creation stage is ready for implementation. During the testing stage, formally controlled and focused testing is performed to uncover errors and bugs in the application that need to be resolved. There are a number of specific validation tests that are performed during the testing stage (requirements validation, system integration, interface, performance, usability, and user acceptance). Additional tests may be conducted to validate documentation, training, contingency plans, and installation. The testing stage ends with a review to determine readiness to proceed to the operation stage.

3.8 Operation Analysis

In operation stage, the augmented reality application will be fully operated and tested by using android smartphone or tablet devices. A questionnaire will be used to assess the feedback from the users of the AR application with specified parameters regarding the performance and the usefulness of the application. All features in the augmented reality application should working properly during this stage in order to proceed to the next stage. And if it doesn't meet the requirement, it will be back to the augmented reality object creation phase.

3.9 Conclusion

It is the last step which is consists of conclusion and recommendation. All of the analysis results will be described on the conclusion part. Meanwhile, recommendations also provided for further research to start implementing augmented reality technology to improve the efficiency of training program.

3.10 Research Schedule

Table 3.1 Research Schedule

No.	Activity	February				March				April				May			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1.	Preparatory Stage																
	a. Problem Identification																
	b. Literature Study																
	c. P1 Exam																
2.	1st Phase Development																
	a. Diesel Engine 3D model creation																
	b. P2 Exam																
3.	2nd Phase Development																
	a. AR Application Development																
	b. Scenario Creation																
4.	Final Stage																
	c. Testing																
	d. Operation Analysis																
	e. Final Report Production																
	f. P3 Exam																

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CHAPTER IV
DATA ANALYSIS

4.1 Data Collection

4.1.1 Diesel Engine Data

The data consists of:

a) Diesel Engine Product Guide
   The data is used as the guidance to create the proper diesel engine dimension in the augmented reality application.
b) Diesel Engine Parts Catalogue
   The catalogue is used to identify the main components of the diesel engine that need to be installed in order to create a complete diesel engine built.
c) Diesel Engine Parts Drawing
   The drawing is used as the basis to identify the shape of the components, dimension, as well as orientation of the components and to create the diesel engine 3D objects in augmented reality application.

4.1.2 Research Object

Figure 4.1 Wärtsilä 8L32 Marine Diesel Engine
Source: www.wartsila.com

4.1.3 Engine Specifications

Table 4.1 Engine Specifications
Source: Wärtsilä 8L32 Product Guide

Engine Specifications	
Brand	Wärtsilä
Model	8L32
Type	In-Line 8, 4-Stroke Cycle Diesel
Output	4640 kW
Cylinder Bore	320 mm
Stroke	400 mm
Piston Displacement	32.2 l/cylinder
Number of Valves	2 inlet valves 2 exhaust vales
Cylinder Configuration	8 cylinder in-line
Direction of Rotation	Clockwise
Speed	720, 750 rpm
Mean Piston Speed	9.6, 10.0 m/s

4.1.4 Engine Dimensions and Weights

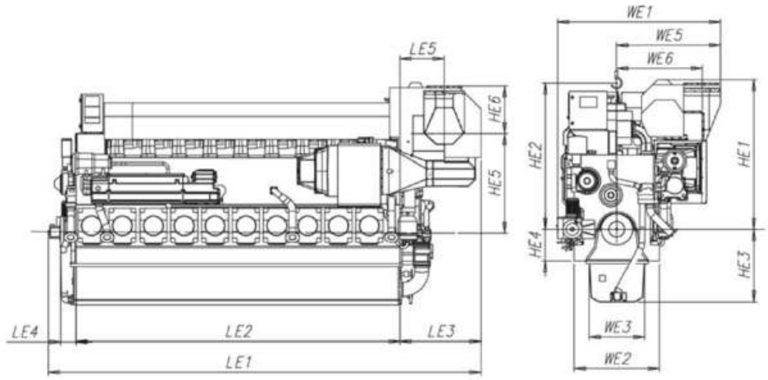


Figure 4.2 Wärtsilä 8L32 Engine Dimensions and Weights
Source: Wärtsilä 8L32 Product Guide

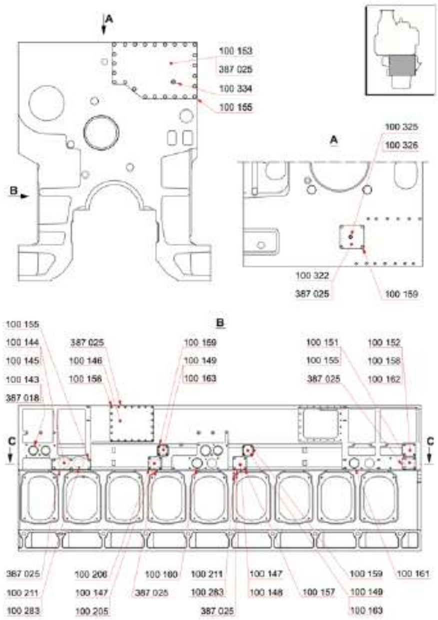
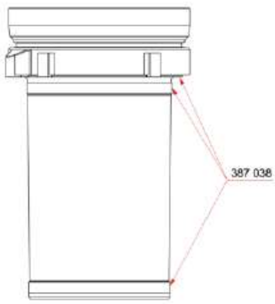
Engine	LE1	HE1	WE1	HE2	HE4	HE3	LE2	LE4	WE3	WE2
W8L32	6379	2375	2610	2345	500	1155	4650	250	880	1350

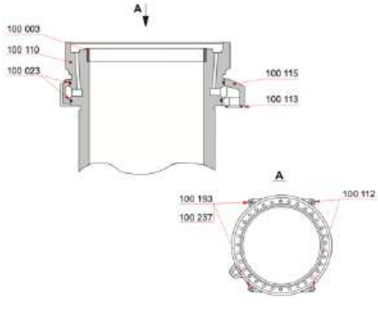
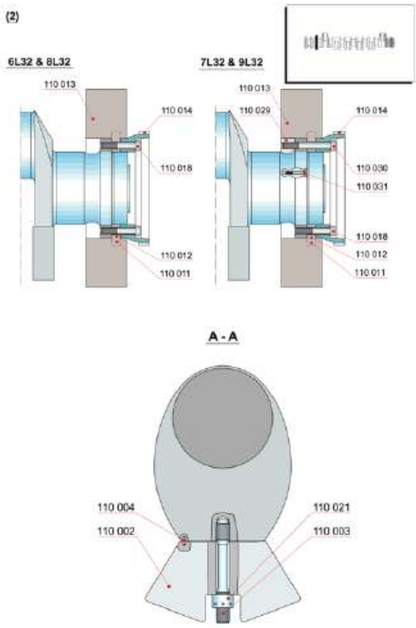
Engine	WE5	LE3	HE5	HE6	WE6	LE5	Weight
W8L32	1650	1285	1780	545	1340	705	43.6

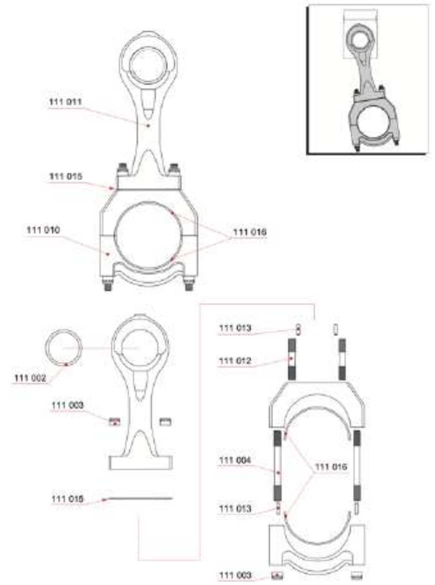
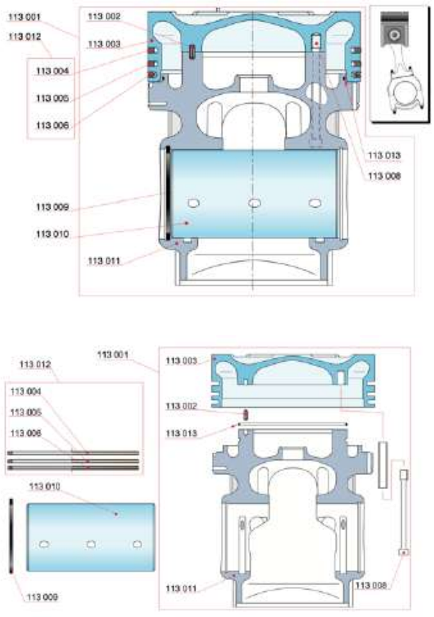
4.1.5 Diesel Engine Main Component List

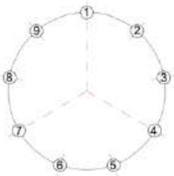
Diesel engine components list is generated from the Wärtsilä 8L32 Parts Catalogue. Only main components of the diesel engine that will be transformed into 3D model for the Diesel AR application.

Table 4.2 Main Components List
Source: Wärtsilä 8L32 Parts Catalogue

No.	Equipment Name	Drawing	Quantity
1.	Engine Block		1
2.	Cylinder Liner		8

No.	Equipment Name	Drawing	Quantity
			
3.	Crankshaft		8

No.	Equipment Name	Drawing	Quantity
4.	Connecting Rod		8
5.	Piston		8

<table>
<tr><th>No.</th><th>Equipment Name</th><th>Drawing</th><th>Quantity</th></tr>
<tr><td>6.</td><td>Flywheel</td><td>
<table>
<tr><th>Engine type</th><th>Location of fitted bolts</th><th>* 114 002
Number of fitted bolts</th><th>* 114 004
Number of normal screws</th></tr>
<tr><td>BL32</td><td>1, 3, 5, 7</td><td>4</td><td>5</td></tr>
<tr><td>BL32</td><td>1, 3, 5, 7, 9</td><td>5</td><td>4</td></tr>
<tr><td>BL32</td><td>1, 3, 4, 6, 7, 9</td><td>6</td><td>3</td></tr>
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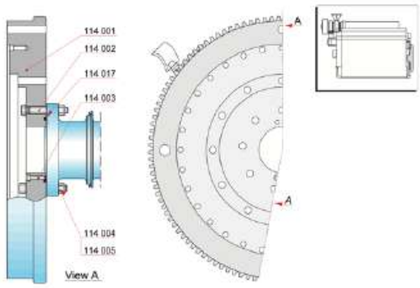
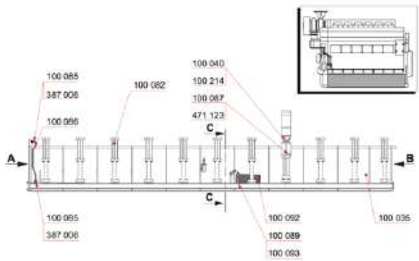
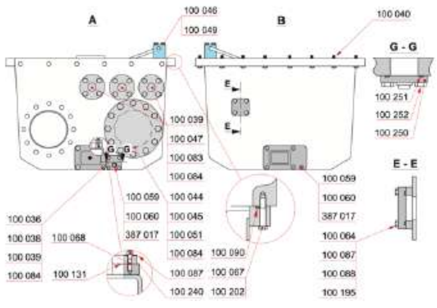
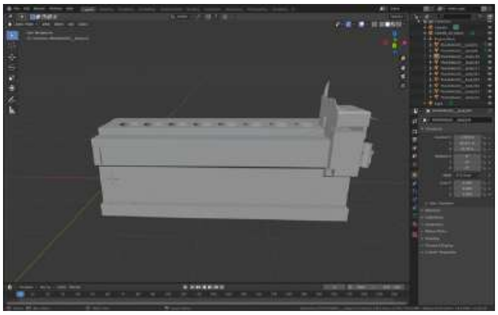
</td><td>1</td></tr>
<tr><td>7.</td><td>Wet Sump</td><td>
</td><td>1</td></tr>
</table>

4.2 3D Object Modelling

3D modelling is the process of creating a visual representation of a 3-dimensional object or shape. The object that produced by this process is called 3D model and will be used for computer-generated (CG) design. The 3D model created by using combination of Autodesk Fusion 360 software and Blender software due to their capabilities to create precise object and well-rendered 3D model for the AR application. The creation of 3D model based on the list of components from Wartsila 8L32 Parts Catalogue.

The 3D object of each components is created separately by using this software. Every detail and dimension are calculated precisely in order to present the real representation of the diesel engine components to the user. The 3D object will be imported to Unity3D software as the basic assets for creating the Diesel AR application.

4.2.1 Engine Block



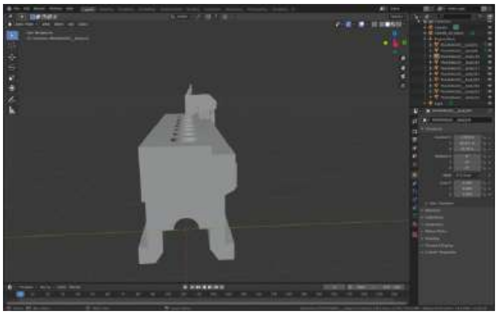


Figure 4.3 Engine Block 3D Model
Source: Author

4.2.2 Crankshaft

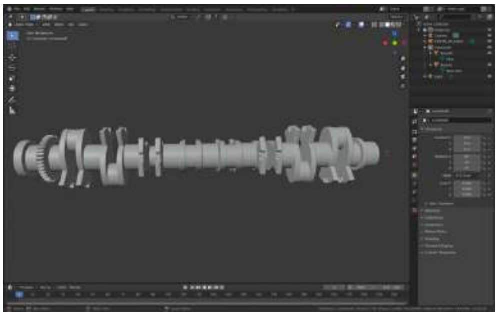


Figure 4.4 Crankshaft 3D Model
Source: Author

4.2.2 Connecting Rod

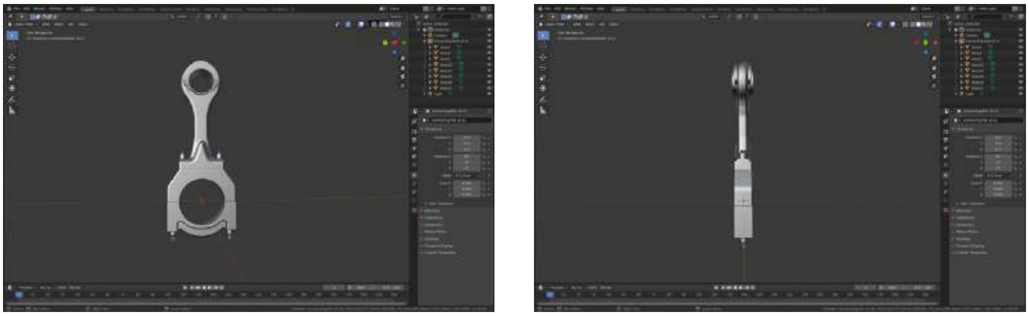


Figure 4.5 Connecting Rod 3D Model
Source: Author

4.2.3 Piston

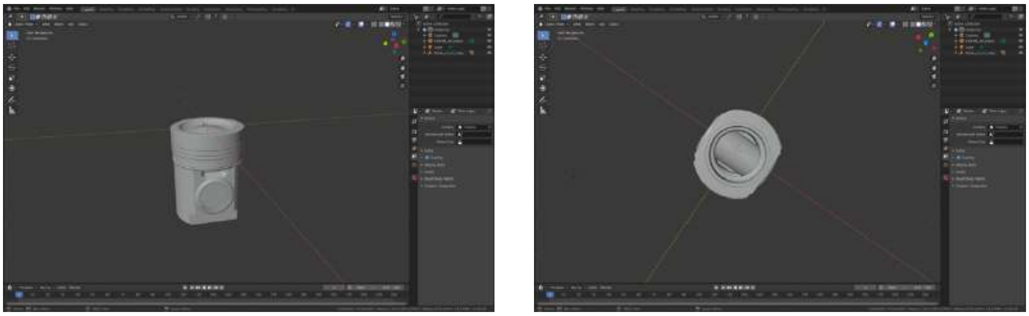


Figure 4.6 Piston 3D Model
Source: Author

4.2.4 Cylinder Liner

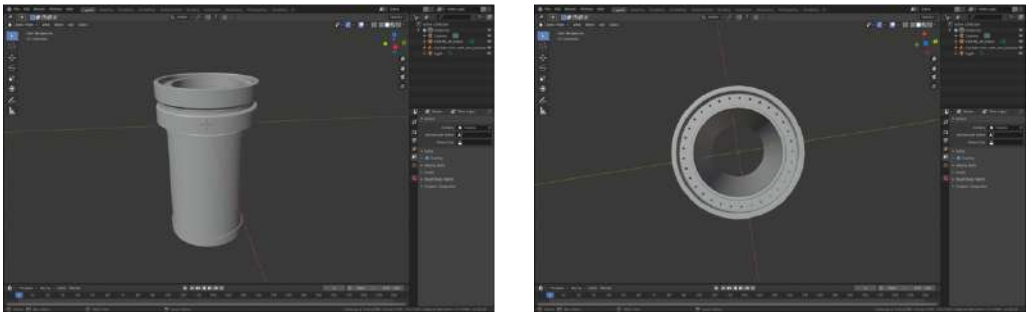


Figure 4.7 Cylinder Liner 3D Model
Source: Author

4.2.5 Flywheel

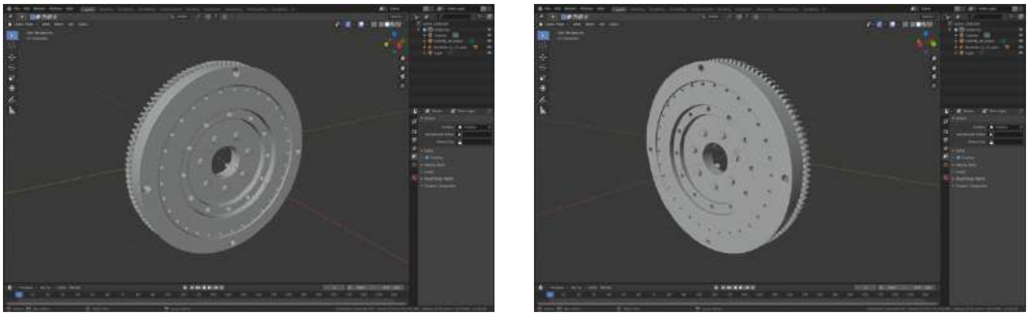


Figure 4.8 Flywheel 3D Model
Source: Author

4.2.6 Wet Sump

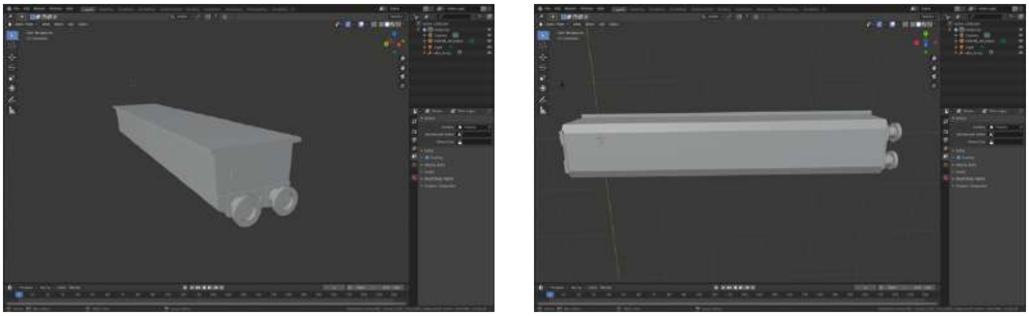


Figure 4.9 Wet Sump 3D Model
Source: Author

The diesel engine main components 3D model that has been created will be used as the main focus of the Diesel AR application, because those are the main components that will be presented to the user including with the detail knowledge of each component. Although during the development, there are a lot of other components that also been created but cannot mentioned in this section.

4.3 Augmented Reality Application Development

In this phase, will be explained the development of augmented reality application from the 3D model rendering into final android application. In order to develop a good augmented reality application, there are several things to consider. Most AR application superimpose 3D object or text over real-time condition that are processed by the user smartphone device. The augmented reality application development will possess a combination of skills including 3D modelling, computer vision, and imaging processes.

4.3.1 3D Model Assembly and Rendering

The 3D model created by using Autodesk Fusion 360 and Blender software is assembled and rendered by using Cinema4D software prior to be imported to Unity3D software. The assembly process gathered all 3D object of the diesel engine components into one full diesel engine form, including the precise dimension, location, and orientation. And the rendering process is conducted to create the materials mask, sculpting, UV edit, bodypaint 3D, and other parameters to make the 3D model looks real.

Figure 4.10 3D Model Assembly and Rendering using Cinema4D
Source: Author

The rendering process is an important part to create the images look realistic and credible and to align the diesel engine components with real-world environment. Both of these elements should be developed correctly in order to present the diesel engine 3D object and information as real as possible so that the user can get maximum benefits.

4.3.2 Marker Design

An augmented reality application needs “marker”, which is an identification device that is used as an input for the application to scan and recognize the unique form that has been installed within the application to trigger the augmented 3D object. The application use the smartphone camera to detect the marker and shows the 3D object. In the Diesel AR application, the author develop the application icon and it will be used as the marker for the application. Once the marker is detected and recognized by the application, the 3D model of the diesel engine will appear. The marker shown in figure below.

Figure 4.11 Diesel AR Marker Design
Source: Author

4.3.3 UI/UX Design

The User Interface/User Experience design is the process of creating the application interface to satisfy the user by providing the easiest usability, accessibility, and pleasure during the user experience when using the application. UI/UX designing process is conducted with Adobe Photoshop software.

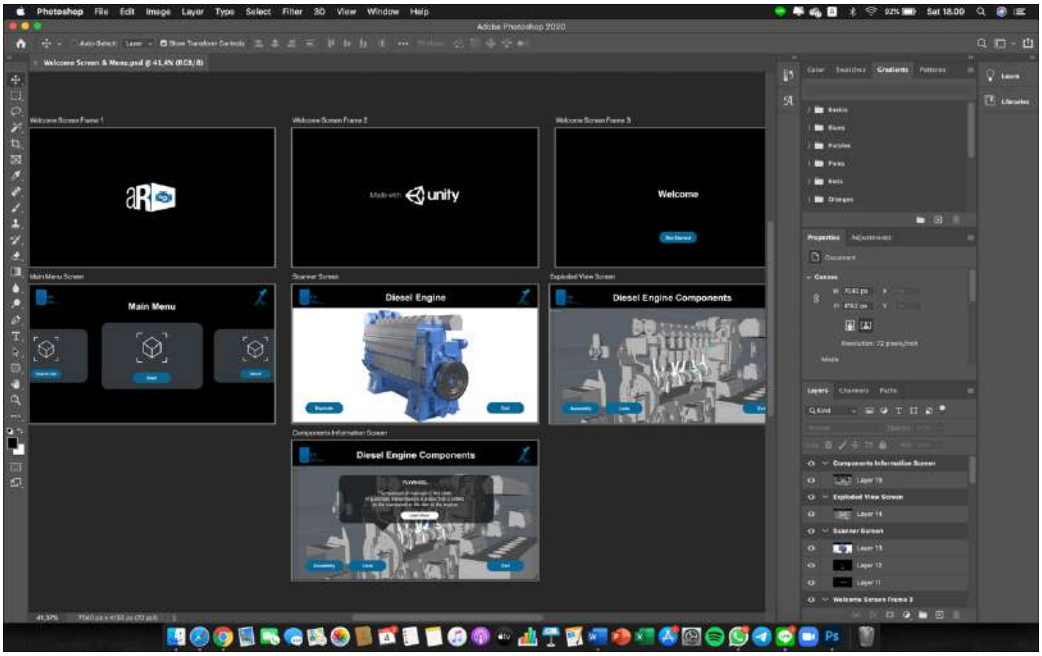


Figure 4.12 UI/UX Designing Process using Adobe Photoshop
Source: Author

4.3.4 Android Application Development

Diesel engine 3D model that has been created will be processed as an input for the augmented reality application using Unity3D software and will be assembled with other resources such as assets, scripts, texts, graphics, animation, sounds, and hardware in order to develop the augmented environment. Unity is known to be the most popular and powerful game development engine worldwide, and it also can be utilized to develop augmented reality application with powerful effects.

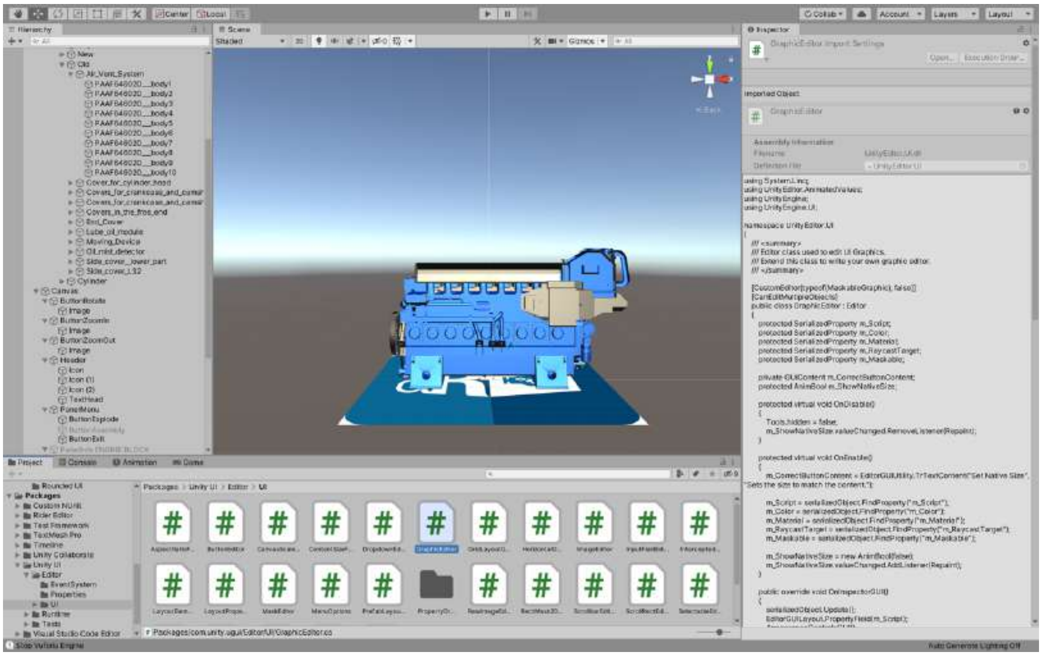


Figure 4.13 Android Application Development using Unity3D
Source: Author

In order to develop an augmented reality application, Unity3D software need additional plugin which is called “Vuforia SDK” that is specifically used as the programming engine for augmented reality application. The planar images and 3D object will be tracked and recognized in real time by this plugin with the help of computer vision technology. This plugin comprises all features needed by an augmented reality application such as transforming the 3D model into interactive animation, develop specific augmented reality experiences, and many more. This plugin provides the source code, programming tools, emulator, and libraries required to build the augmented reality application and it is the most powerful plugin in the market.

4.4 Augmented Reality Application Final Result

Once the application development is completed, the Diesel AR application is ready to use. The result of the development is in the form of ".apk" or android application installer file. The user interface of the application shown in figure below.

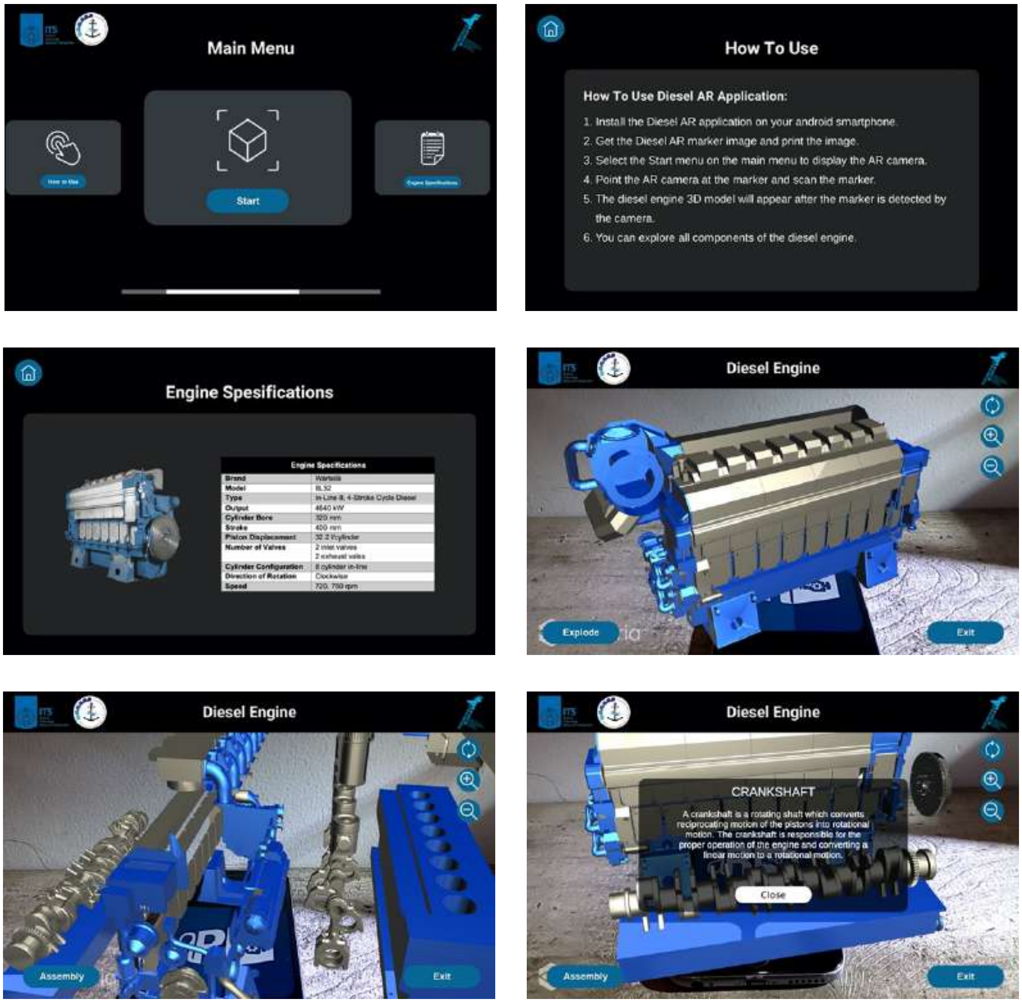


Figure 4.14 Diesel AR Application Final Result
Source: Author

Inside the Diesel AR application, there will be several main menu that can be chosen, namely: How to use, Start, Engine Specification, and About. The users can start to scan the marker with Start Menu to show the 3D object of the diesel engine. The diesel engine 3D object can be rotated, zoom in, and zoom out. It also can be shown in exploded view to give better insight about the components. Once selected component is clicked, there will be a pop up that gives related information about the diesel engine components.

4.5 Application Testing

The Diesel AR application is tested prior to public launching or operation phase. The testing is performed to determine whether the augmented reality application and preliminarily tested during the creation stage is ready for implementation. The testing is conducted through activities for the entire application features with the motive of finding errors in application. The application tested on 3 android devices with different brand, screen size, and specifications. The testing result shown in table below.

Table 4.3 Application Testing Devices
Source: Author

No.	Specifications
1.	• Device Name : Samsung Galaxy Tab S5e • OS Version : Android 9.0.0 (Pie) • RAM : 4 GB • Processor : Octa-core 2.0 GHz • Camera : 13.0 MP • Screen Resolution : 10.5” (2560x1600 pixels)
2.	• Device Name : Lenovo Vibe K5 Plus • OS Version : Android 5.1 (Lollipop), Upgraded to Android 8.1 (Oreo) • RAM : 2 GB • Processor : Octa-core (4x1.5 GHz & 4x1.2 GHz) • Camera : 13.0 MP • Screen Resolution : 5.0” (1080x1920 pixels)
3.	• Device Name : Oppo A3S • OS Version : Android 8.1 (Oreo) • RAM : 2 GB • Processor : Octa-core 1.8 GHz • Camera : 13.0 MP • Screen Resolution : 6.2” (720x1520 pixels)

The diesel AR application is tested in those devices starting from installation of the application, starting up the application, access all menu and features within the application, into exiting and uninstalling the application from the devices. Every aspects is tested carefully to ensure that the application deliver maximum performance to enhance the user experiences. The application testing result shown in Table 4.4.

Table 4.4 Application Testing Result
Source: Author

No.	Parameters	Test Result		
		Device 1	Device 2	Device 3
1.	App Installation	✓	✓	✓
2.	Start-up	✓	✓	✓
3.	Responsive UI / UX Design	✓	✓	-
4.	Access Main Menu	✓	✓	✓
5.	Open "Start" Menu	✓	✓	✓
6.	Open "How to Use" Menu	✓	✓	✓
7.	Open "Engine Specifications" Menu	✓	✓	✓
8.	Open "About" Menu	✓	✓	✓
9.	Scan Markers	✓	✓	✓
10.	3D Model Show	✓	✓	✓
11.	Zoom and Rotate 3D Model	✓	✓	✓
12.	Switch to 3D Model Exploded View	✓	✓	✓
13.	Diesel engine components detail pop-up	✓	✓	✓
14.	Walk-through the entire 3D model from 360 degrees.	✓	✓	✓
15.	Assembly	✓	✓	✓
16.	Exit	✓	✓	✓
17.	App Uninstall	✓	✓	✓

According to the testing result above, shown that the majority of function is running very well in all devices. But, there is minor issue related with display or UI/UX design which comes from device 3. This issues caused by the uncommon aspect ratio of device 3, which have the resolution of 720x1520 pixels and 19:9 aspect ratio. Meanwhile, the majority of android devices have aspect ratio of 16:10 / 16:9. This uncommon aspect ratio cause unresponsive UI/UX Design in the device 3.

Besides that, there is no other issues related with the operation of the application. The Diesel AR application is running well and smooth on those 3 devices, and every function can be executed correctly. The testing process is also done to check the integration of the smartphone hardware with the application such as camera, gyroscope sensors, scanner, etc to ensure the compatibility of the application with the hardware. Every function is performed well, but before going forward to the operation phase, the issue related with unresponsive UI/UX design is fixed and improved. Now, the application UI/UX design is responsive for major android smartphone display resolution available on the market and there will be no issues again.

4.6 Application Operation Analysis

The development of Diesel AR application is completed and ready for public launching. In this step, the author is gathering the user feedback by using online questionnaire. The form of the operation analysis is to ask respondents to run this application, the number of respondents targeted is 10 people. After the respondents have finished using the application, the respondents will be asked to fill out the questionnaire. Respondents will be given ten main questions on the questionnaire, with weights ranging from one to five, where one shows the lowest value and five shows the highest value. Diesel AR application user experience feedback questionnaire :

1. Name :
2. Occupation :
3. Smartphone Brand and Model :

Table 4.5 List of Questions
Source: Author

No.	Question	Score
1.	Did you successfully install the Diesel AR application on your Smartphone?	
2.	What was your first impression when you use the Diesel AR Application?	
3.	Does the Diesel AR Application user interface design is easy to understand and operate?	
4.	Does the information in Diesel AR Application clearly presented?	
5.	Does the Diesel AR Application is running well in your smartphone device?	
6.	How satisfied are you with the features and onboarding experience of the Diesel AR application?	
7.	How much did you understand about diesel engine and the components?	
8.	Does the application helps to increase the knowledge about Diesel Engine and the components?	
9.	Do you think the Diesel AR application is powerful as complementary learning media in the class?	
10.	How likely is it that you could recommend the Diesel AR Application to a friend or colleague?	

Questionnaire Link :
bit.ly/DieselAR-Questionnaire

Scan to try Diesel AR Application :

4.6.1 Questionnaire Result

The result of the online questionnaire is discussed in this section. Below are the devices that is used by respondents to try Diesel AR Application :

1. Samsung Galaxy S10 (2)
2. Pocophone F1
3. Samsung Galaxy A70
4. Samsung Galaxy A50
5. Realme i5
6. Vivo V11
7. Samsung Galaxy A30
8. Sony Xperia
9. Xiaomi Redmi Note 4X

Table 4.6 Questionnaire Result
Source: Author

No.	Question	Score from Respondents					Total
		1	2	3	4	5	
1.	Did you successfully install the Diesel AR application on your Smartphone?	0	0	0	0	10	10
2.	What was your first impression when you use the Diesel AR Application?	0	0	0	3	7	10
3.	Does the Diesel AR Application user interface design is easy to understand and operate?	0	0	0	2	8	10
4.	Does the information in Diesel AR Application clearly presented?	0	0	1	5	4	10
5.	Does the Diesel AR Application is running well in your smartphone device?	0	0	0	2	8	10
6.	How satisfied are you with the features and onboarding experience of the Diesel AR application?	0	0	0	4	6	10
7.	How much did you understand about diesel engine and the components?	0	0	1	6	3	10
8.	Does the application helps to increase the knowledge about Diesel Engine and the components?	0	1	0	3	6	10
9.	Do you think the Diesel AR application is powerful as complementary learning media in the class?	0	0	1	3	6	10
10.	How likely is it that you could recommend the Diesel AR Application to a friend or colleague?	0	0	0	3	7	10

4.6.2 Questionnaire Result Analysis

Based on the results of the questionnaire that has been obtained, the value and percentage of each question can be acquired. To find the percentage of each question, the Likert equation is used with the following formula:

$$P = \frac{S}{\text{Ideal Value}} \text{ x } 100\%$$

With,

- P = Percentage
- S = The frequency multiplied by the value of the answer
- Ideal Value = The highest value multiplied by the number of responses
  = 5 x 10
  = 50

Based on the formula above, the value and percentage of each question can be calculated as follows:

1. Did you successfully install the Diesel AR application on your Smartphone?
   Scale : 1 – 5
   Remark : No – Yes

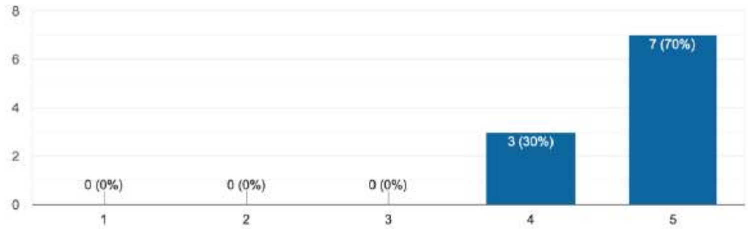
Score	Respondent	Total Score
1	0	0
2	0	0
3	0	0
4	0	0
5	10	50
Total	10	50
Average Score		**5**

The percentage can be calculated as follows:

$$P = \frac{50}{50} X\ 100\% = 100\%$$

From the result, can be concluded that 100% of the user can successfully install the Diesel AR application into their android device without any problem.

2. What was your first impression when you use the Diesel AR Application?
Result :



Very Bad *Very Good*

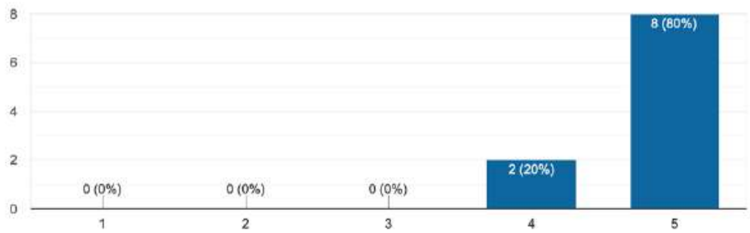
Score	Respondent	Total Score
1	0	0
2	0	0
3	0	0
4	3	12
5	7	35
Total	10	47
Average Score		**4.7**

The percentage can be calculated as follows:

$$P = \frac{47}{50} X\ 100\% = 94\%$$

From the result, can be concluded that most of the users have a good first impression when using the Diesel AR application.

3. Does the Diesel AR Application user interface design is easy to understand and operate?
Result :



Not Understandable *Understandable*

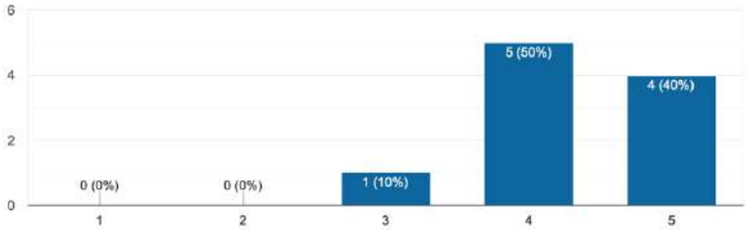
Score	Respondent	Total Score
1	0	0
2	0	0
3	0	0
4	2	8
5	8	40
Total	10	48
Average Score		**4.8**

The percentage can be calculated as follows:

$$P = \frac{48}{50} X\ 100\% = 96\%$$

From the result, can be concluded that the user interface of Diesel Application is easy to understand and to operate by the users.

4. Does the information in Diesel AR Application clearly presented?
Result :



Not Clear *Very Clear*

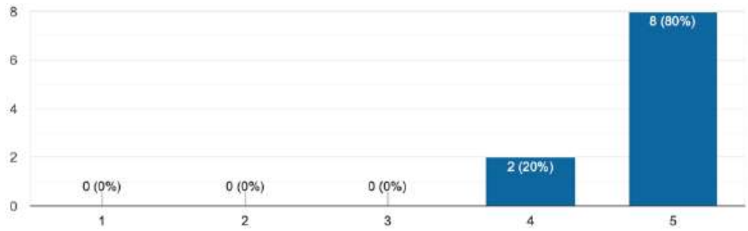
Score	Respondent	Total Score
1	0	0
2	0	0
3	1	3
4	5	20
5	4	20
Total	10	43
Average Score		**4.3**

The percentage can be calculated as follows:

$$P = \frac{43}{50} X\ 100\% = 86\%$$

From the result, can be concluded that the information in Diesel AR application is clearly presented.

5. Does the Diesel AR Application is running well in your smartphone device?
Result :



Very Bad *Very Well*

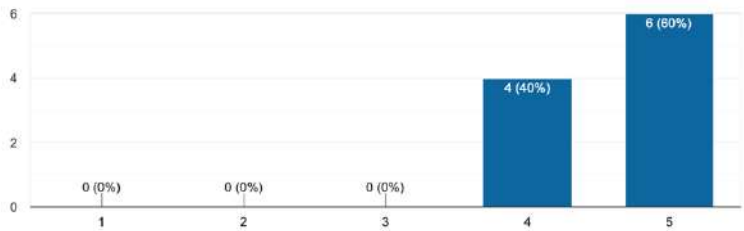
Score	Respondent	Total Score
1	0	0
2	0	0
3	0	0
4	2	8
5	8	40
Total	10	48
Average Score		**4.8**

The percentage can be calculated as follows:

$$P = \frac{48}{50} X\ 100\% = 96\%$$

From the result, can be concluded that the Diesel AR application is running well in the user android smartphone devices.

6. How satisfied are you with the features and onboarding experience of the Diesel AR application?
Result :



Not Satisfied *Very Satisfied*

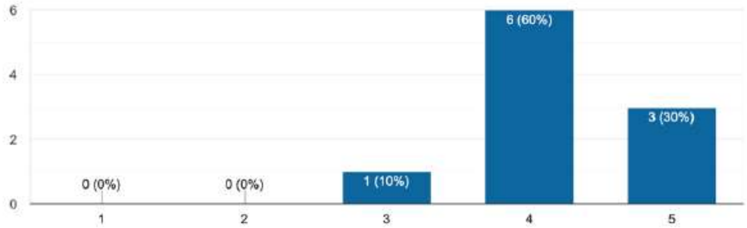
Score	Respondent	Total Score
1	0	0
2	0	0
3	0	0
4	4	16
5	6	30
Total	10	46
Average Score		**4.6**

The percentage can be calculated as follows:

$$P = \frac{46}{50} X\ 100\% = 92\%$$

From the result, can be concluded that the users is satisfied with the features and onboarding experiences provided by Diesel AR application.

7. How much did you understand about diesel engine and the components?
Result :



Do Not Understand *Very Understand*

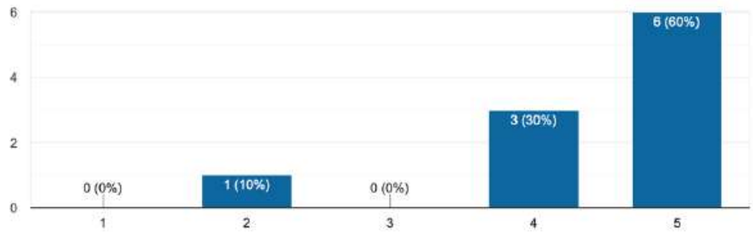
Score	Respondent	Total Score
1	0	0
2	0	0
3	1	3
4	6	24
5	3	15
Total	10	42
Average Score		**4.2**

The percentage can be calculated as follows:

$$P = \frac{42}{50} X\ 100\% = 84\%$$

From the result, can be concluded that most of the users have sufficient knowledge about diesel engine and the components.

8. Does the application helps to increase the knowledge about Diesel Engine and the components?
Result :



Not Helping *Very Helpful*

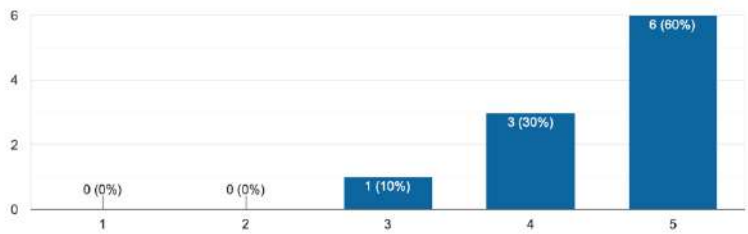
Score	Respondent	Total Score
1	0	0
2	1	2
3	0	0
4	3	12
5	6	30
Total	10	44
Average Score		**4.4**

The percentage can be calculated as follows:

$$P = \frac{44}{50} X\ 100\% = 88\%$$

From the result, can be concluded that the Diesel AR application is helpful to increase the knowledge about diesel engine and the components.

9. Do you think the Diesel AR application is powerful as complementary learning media in the class?
Result :



Not at all *Very Powerful*

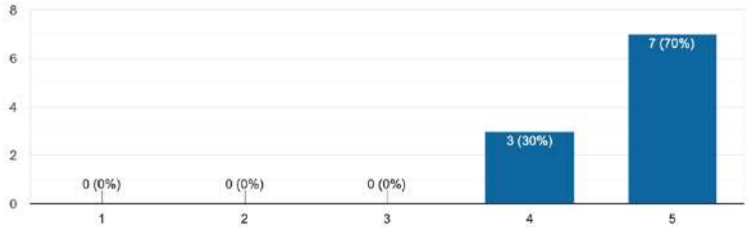
Score	Respondent	Total Score
1	0	0
2	0	0
3	1	3
4	3	12
5	6	30
Total	10	45
Average Score		**4.5**

The percentage can be calculated as follows:

$$P = \frac{45}{50} X\ 100\% = 90\%$$

From the result, can be concluded that the Diesel AR application is very powerful as complementary learning media in the class.

10. How likely is it that you could recommend the Diesel AR Application to a friend or colleague?
Result :



Not Recommended *Very Recommended*

Score	Respondent	Total Score
1	0	0
2	0	2
3	0	0
4	3	12
5	7	35
Total	10	47
Average Score		**4.7**

The percentage can be calculated as follows:

$$P = \frac{47}{50} X\ 100\% = 94\%$$

From the result, can be concluded that the most of the users is recommend the Diesel AR application to their friends and colleagues.

Based on the results of the calculation of each question above, then the total value and average percentage of the entire questionnaire can be calculated as follows:

Table 4.7 Questionnaire Total Result
Source: Author

Question No.	Percentage	Total Value	Average Value
1	100%	50	5.0
2	94%	47	4.7
3	96%	48	4.8
4	86%	43	4.3
5	96%	48	4.8
6	92%	46	4.6
7	84%	42	4.2
8	88%	44	4.4
9	90%	45	4.5
10	94%	47	4.7
Total	920%	460	46
Average	92%	46	4.6

The above data can be used to assess the results of the assessment of all respondents on the quality of the application, while the steps are as follows:

1. Determine the Maximum Value
   The maximum value is the largest answer value multiplied by the number of questions, multiplied by the number of respondents.
   Highest Value = 5
   Number of Questions = 10
   Number of Respondent = 10
   Maximum Value = 5 x 10 x 10
   = 500

2. Determine the Minimum Value
   The minimum value is the smallest answer value multiplied by the number of questions, multiplied by the number of respondents.
   Smallest Value = 1
   Number of Questions = 10
   Number of Respondent = 10
   Maximum Value = 1 x 10 x 10
   = 100

3. Determine the Median Value
   Median values can be determined by adding up the maximum and minimum values then dividing them in half.
   Minimum Value = 100
   Maximum Value = 500
   Median Value = (100+500)/2
   = 300

4. Determine the Quartile 1 Value
   Quartile 1 can be determined by adding up the minimum value and the median value then dividing it in half.
   Minimum Value = 100
   Median Value = 300
   Median Value = (100+300)/2
   = 200

5. Determine the Quartile 3 Value
   Quartile 3 can be determined by adding up the Maximum value and the median value then dividing it in half.
   Minimum Value = 500
   Median Value = 300
   Median Value = (500+300)/2
   = 400

From the calculation above, the category of assessment can be created by using the minimum value, maximum value, median, quartile 1, and quartile 3 as follows:

Table 4.7 Questionnaire Final Result
Source: Author

Range	Value	Category
100 - 200	Minimum Value $< x \leq$ Quartile 1	Bad
201 - 300	Quartile 1 $< x \leq$ Median	Sufficient
301 - 400	Median $< x \leq$ Quartile 3	Good
401 - 500	Quartile 3 $< x \leq$ Maximum Value	Excellent

Based on the questionnaire result with the total value of 460, can be concluded that the Diesel AR application is categorized as **Excellent** performance. By this result, the Diesel AR application is ready to be implemented into broader audiences and users.

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CHAPTER V
CONCLUSION

5.1 Conclusion

Based on the result, the conclusion of this research are:

1. Augmented Reality (AR) technology is powerful to be implemented as mobile-based learning media for diesel engine operation training with the main focus to the diesel engine components.
2. Every diesel engine components can be displayed and rendered into 3D model that corresponding with the real condition alongside with information and the location of the components.
3. Utilizing the AR application as mobile-based learning media for diesel engine operation training provide a better understanding to the user by replacing 2D drawing with real-time 3D model with proportional dimension of the diesel engine and its components.
4. Diesel AR application is developed to be compatible with android operating system, various type of smartphone brand, with minimum requirements as follows:
   - Android Version : Android 7 or later
   - RAM : 2 GB
   - Storage : 98.57 MB
   - Processor : Dual Core 1.5 GHz
5. The Diesel AR application is developed with simple user interface that allows users to easily navigate through the entire application in order to perform several tasks, with intuitive, easy to use, simple and that the users can rely on the application. Based on the questionnaire result with the total value of **460**, can be concluded that the Diesel AR application is categorized as **Excellent** performance. By this conclusion, the Diesel AR application is ready to be implemented into broader audiences and users.

5.2 Suggestion

Suggestions of this research are:

1. The Diesel AR application is capable to deliver the knowledge of diesel engine components in an efficient and interesting approach by utilizing the augmented reality technology, but the current application is developed only to present the main components of the diesel engine. There are a lot of other components that is important and can be presented in future development.
2. The Diesel AR application uses marker-based augmented reality, which is requires a “Marker” to scan and recognize the unique form that has been installed within the application to trigger the augmented 3D object. The user need to continuously maintain and ensures that the camera of the smartphone always pointed at the marker in order to keep the 3D object alive.

REFERENCES

Alesky, M., Vartiainen, E., Domova, V., & Naedele, M. (2014). Augmented Reality for Improved Service Delivery. *Proc. IEEE 28th Int. Conf. Adv. Inf. Netw. Appl.*, 382-389.

Azuma, R. (1997). A Survey of Augmented Reality. In Presence: Teleoperators and Virtual Environments.

Azuma, R. (2001). Recent Advances in Augmented Reality. *IEEE*.

Camba, J., & Contero, M. (2015). From Reality to Augmented Reality: Rapid Strategies for Developing Marker-Based AR Content Using Image Capturing and Authoring Tools. *IEEE*.

Carmigniani, J. (2010). Augmented Reality Technologies, Systems and Applications. *Science and Business*.

Challen, B., & Baranescu, R. (1999). *Diesel Engine Reference Book: Second Edition.* Woburn: Butterworth-Heinemann.

Dini, G. (2015). Application of Augmented Reality Techniques in Through-life Engineering Services. *The Fourth International Conference on Through-life Engineering Services*.

Drath, R., & Horch, A. (2014). Industrie 4.0: Hit or Hype? *IEEE Ind. Electron. Mag. Vol. 8, No. 2*, 56-58.

Fiorentino, M. (2013). Augmented Reality on Large Screen for Interactive Maintenance Instructions. *Computers in Industry*.

Fraga-Lamas, P., Fernandez-Carames, T. M., Blanco-Novoa, O., & Vilar-Montesionos, M. A. (2017). Potential Augmented Reality Applications in the Mining Industry. *IEEE*, 13358-13375.

Gedeon, G. (2019). *Diesel Engine Fundamentals.* New York: Continuing Education and Development, Inc.

Gerpen, J. V. (2010). Basics of Diesel Engines and Diesel Fuels. In *The Biodiesel Handbook.* Moscow: Academic Press and AOCS Press.

Horejší, P. (2015). Augmented Reality System for Virtual Training of Parts Assembly. *DAAAM*, 699-706.

Jacobs, J., Webber-Youngman, R., & Wyk, E. v. (2016). Potential Augmented Reality Applications in the Mining Industry.

Kollatsch, C. (2014). Mobile Augmented Reality based Monitoring of Assembly Lines. *Conference on Assembly Technologies and Systems*.

Lamas, P. F. (2018). Potential Augmented Reality Applications in the Mining Industry. *IEEE*.

Li, C., & Tang, B. (2019). Research on The Application of AR Technology Based on Unity3D in Education. *Journal of Physics: Conference Series*.

Li, L., Q, P., & Yu, L. (2010). Research and Application of Unity3d Virtual Display Technology. . *Digital Technology and Applications*.

LI, W. (2019). Research on the Visual Elements of Augmented Reality Assembly Process. *Virtual Reality & Intelligent Hardware*.

Lu, W., & Jin, Y. (2017). Smartphone-based Vuforia+Unity3D Augmented Reality Technology Scheme and Education Application. *Modern Education Technology*, 05:19-25.

Mollenhauer, K., & Schreiner, K. (2010). History and Fundamental Principles of the Diesel Engine. *Springer-Verlag Berlin Heidelberg*.

Neb, A., & Strieg, F. (2018). Generation of AR-enhanced Assembly Instructions based on Assembly Features. *51st CIRP Conference on Manufacturing Systems*.

Palmarini, R. (2017). A Systematic Review of Augmented Reality Applications in Maintenance. *Robotics and Computer–Integrated Manufacturing*.

Procházka, & Koubek. (2010). Augmented Reality Implementation Methods in Mainstream Applications.

Ramirez, H., Mendivil, E. G., Flores, P. R., & Gonzalez, M. C. (2013). Authoring Software for Augmented Reality applications for the use of maintenance and training process. *2013 International Conference on Virtual and Augmented Reality in Education*.

Smparounis, K., Mavrikios, D., Pappas, M., Xanthakis, V., Vigano, G., & Pentenrieder, K. (2008). A Virtual and Augmented Reality Approach to Collaborative Product Design and Demonstration. *IEEE*, 1-9.

Walshaw, T. D. (1953). *Diesel Engine Design: Second Edition.* London, England: George Newnes Ltd.

Yan, J., Meng, Y., & Li, L. (2017). Industrial Big Data in an Industry 4.0 Environment: Challenges, Schemes, and Applications for Predictive Maintenance. *IEE Access, Vol. 5*, 23484-23491.

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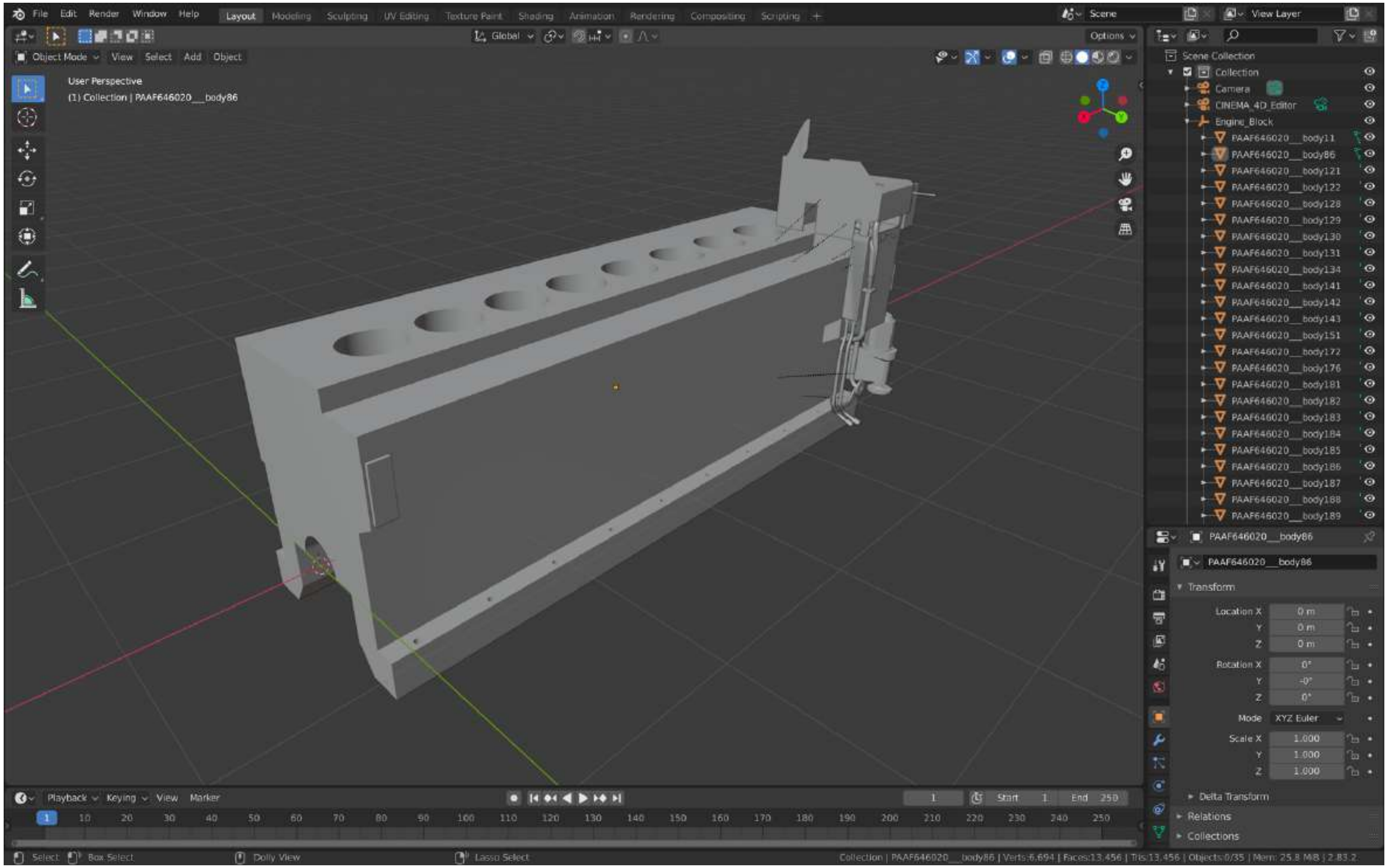
DIESEL ENGINE 3D MODEL CREATION USING BLENDER SOFTWARE



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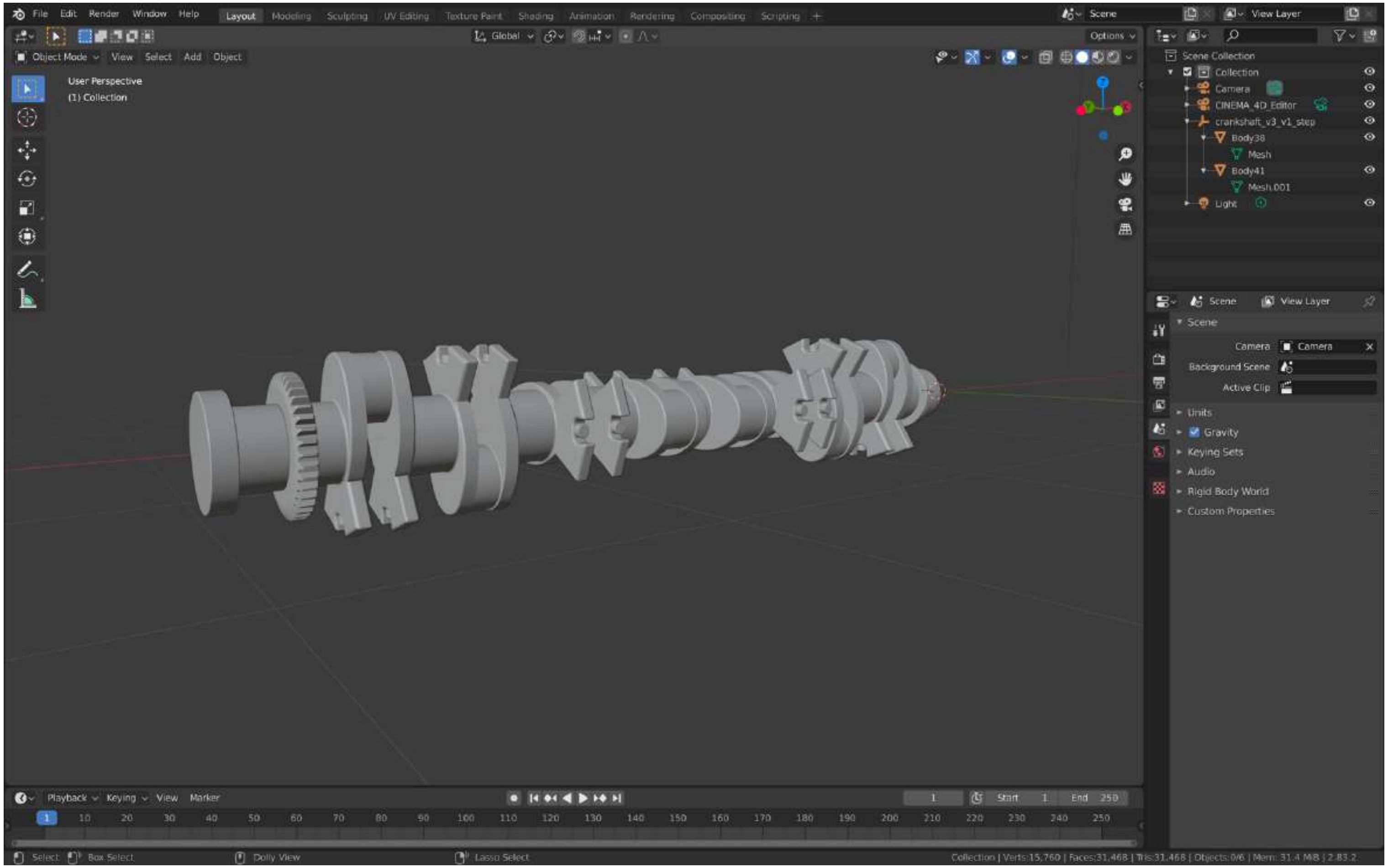


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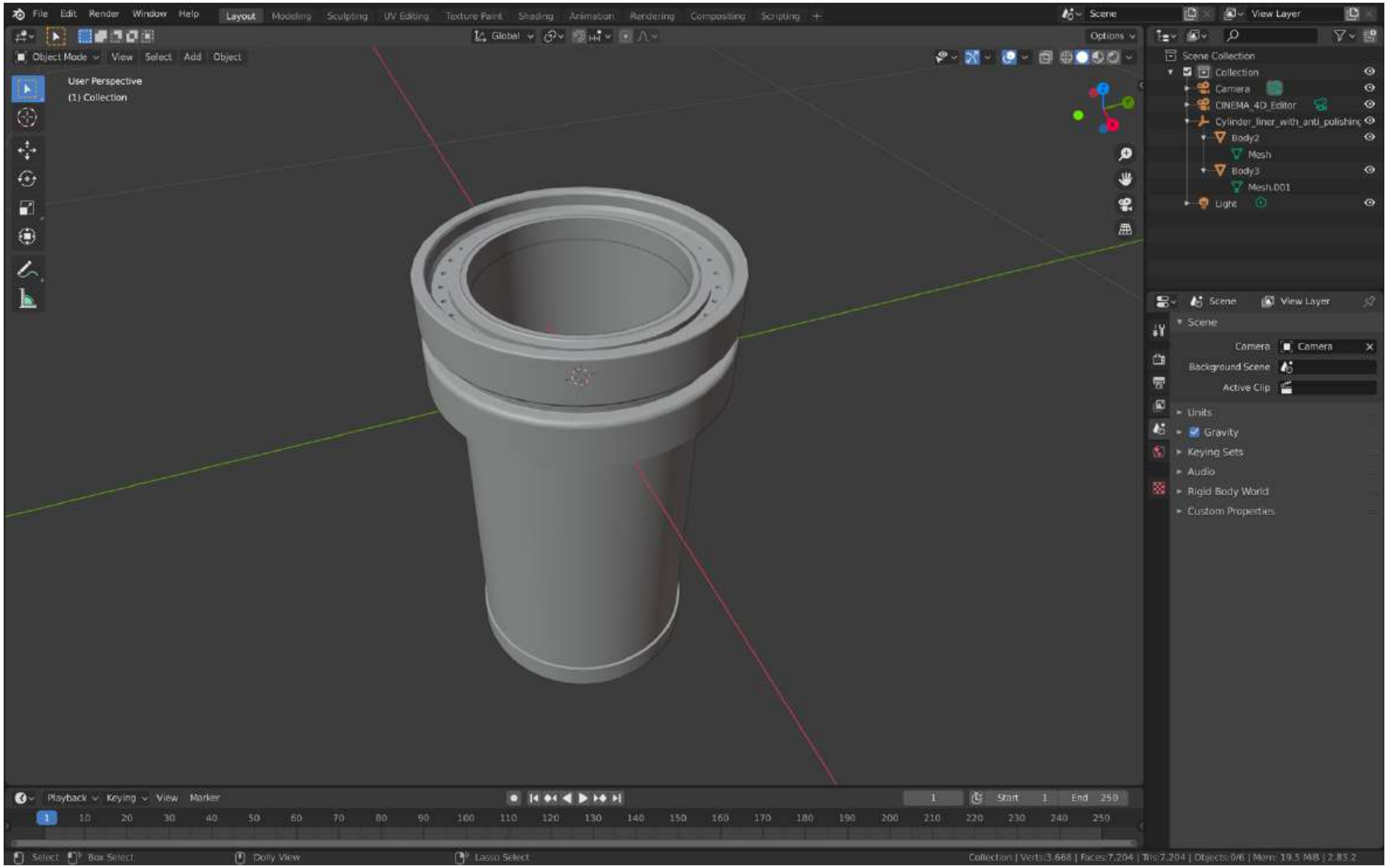
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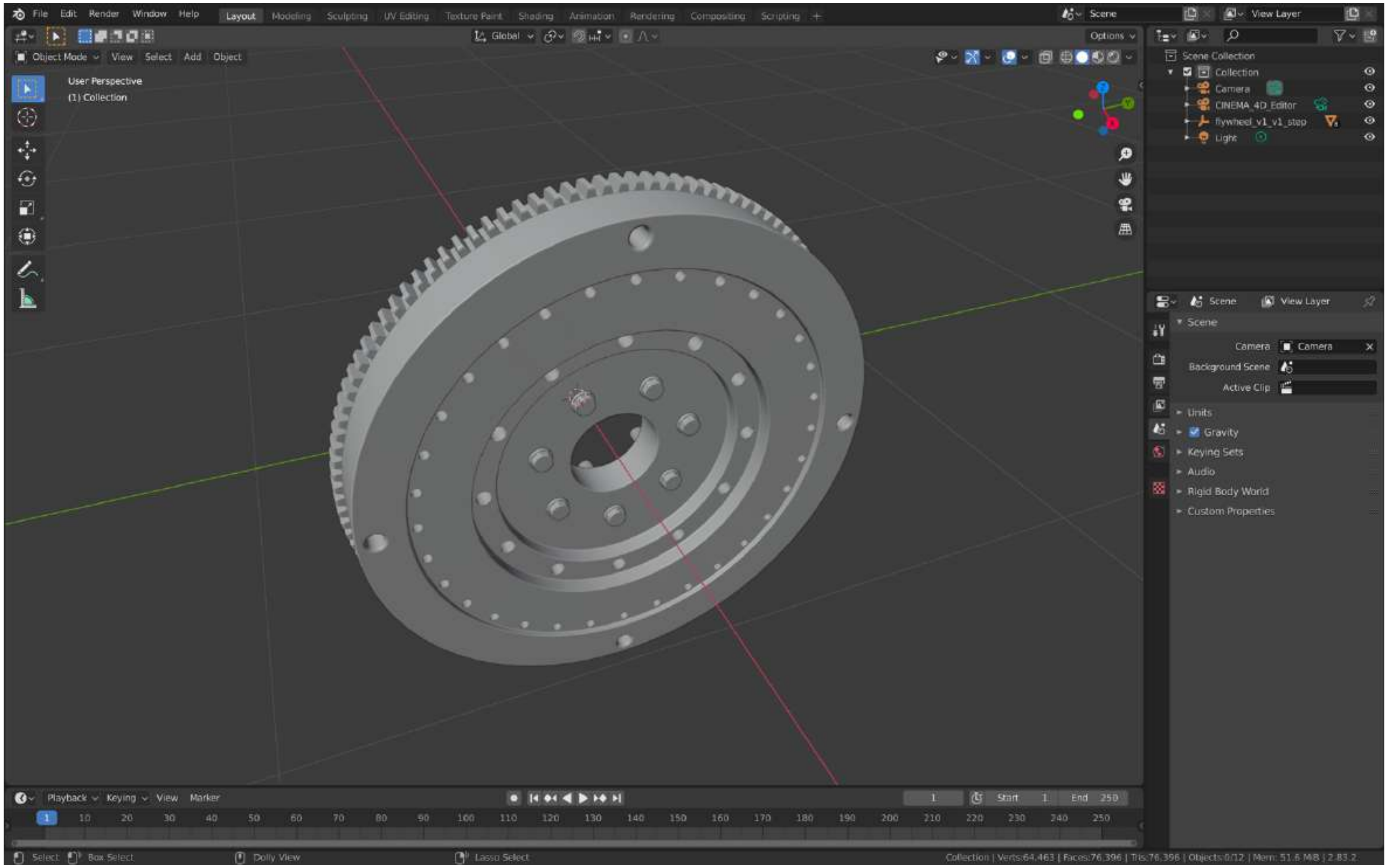
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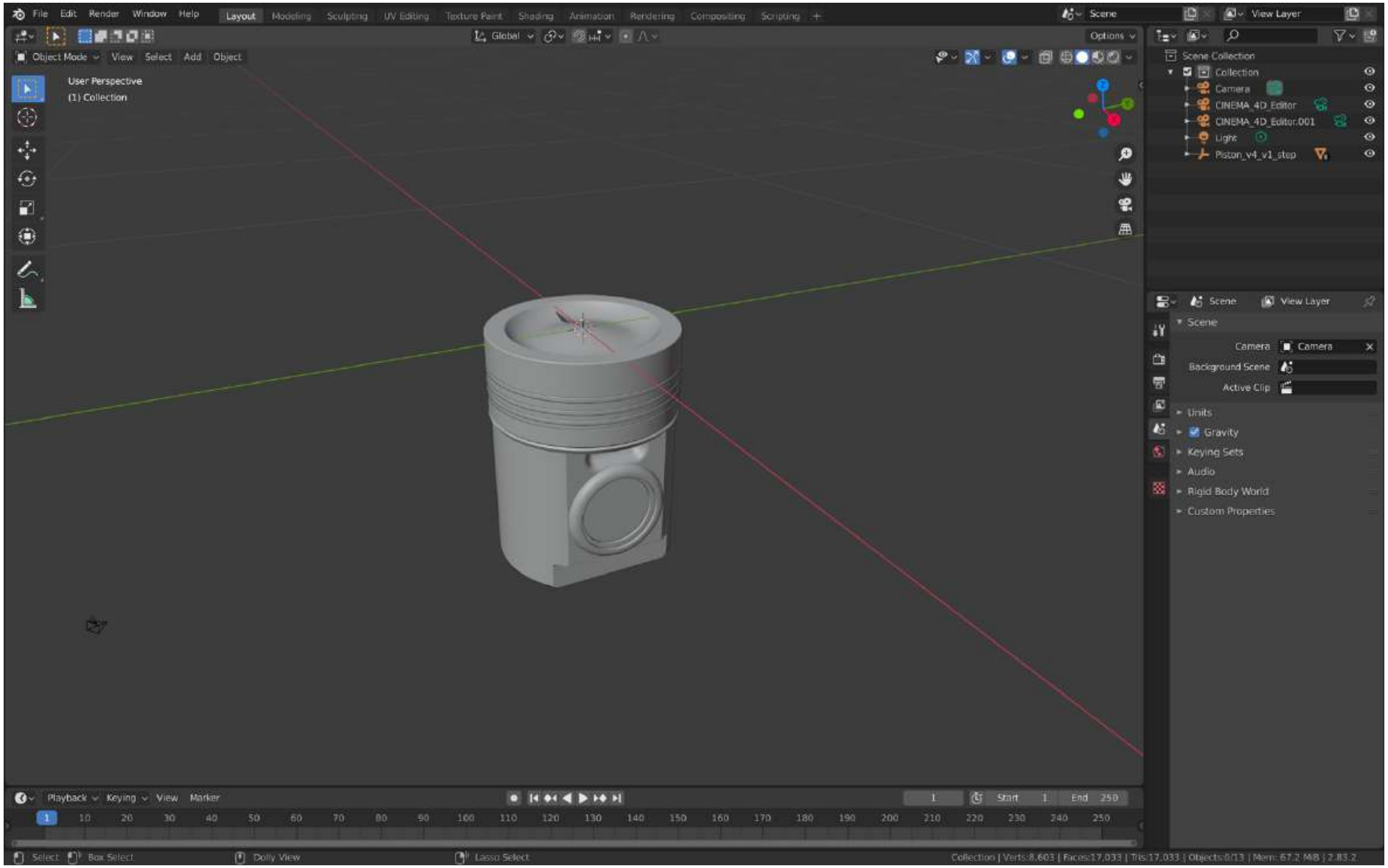
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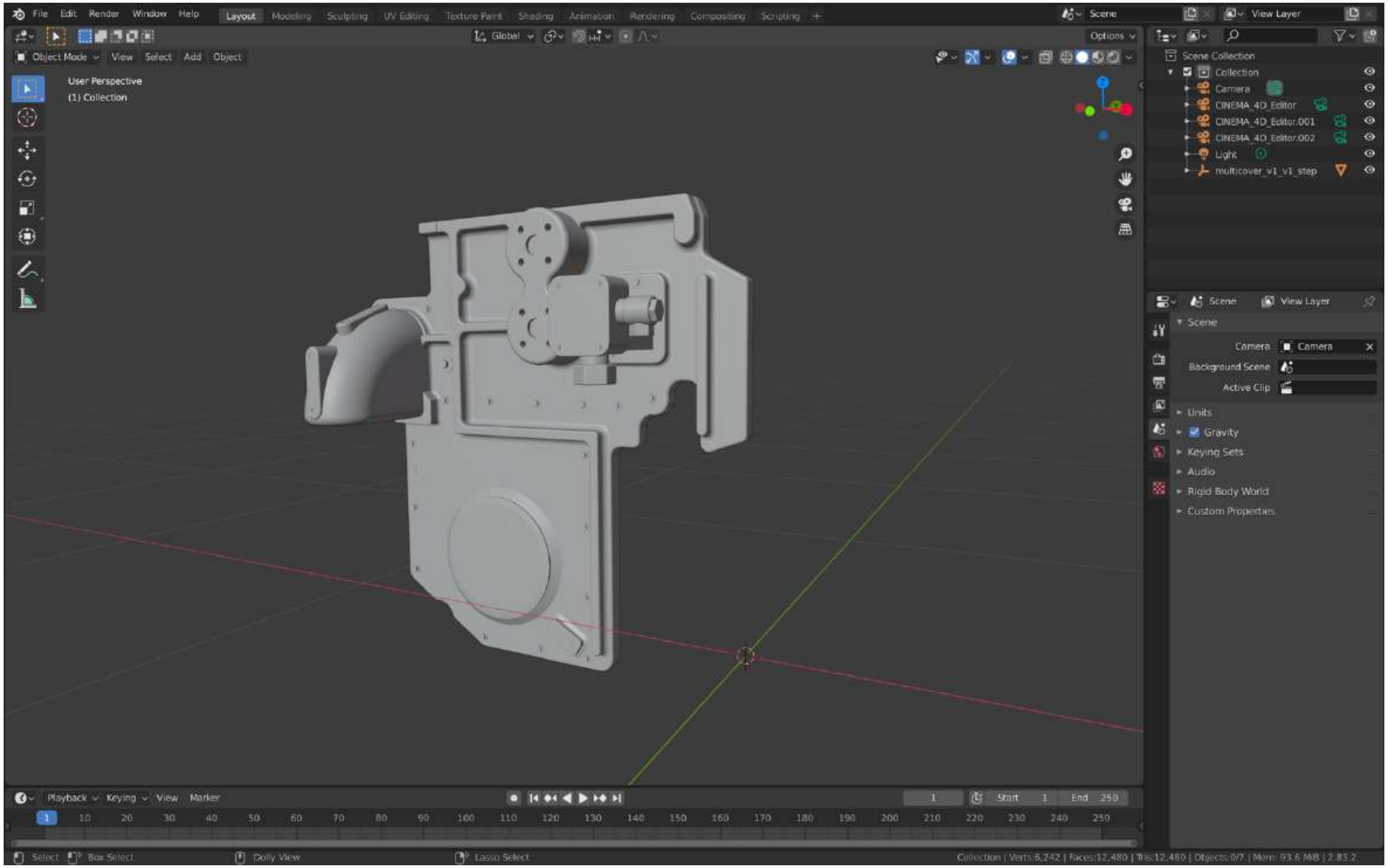
DIESEL ENGINE 3D MODEL CREATION USING BLENDER SOFTWARE



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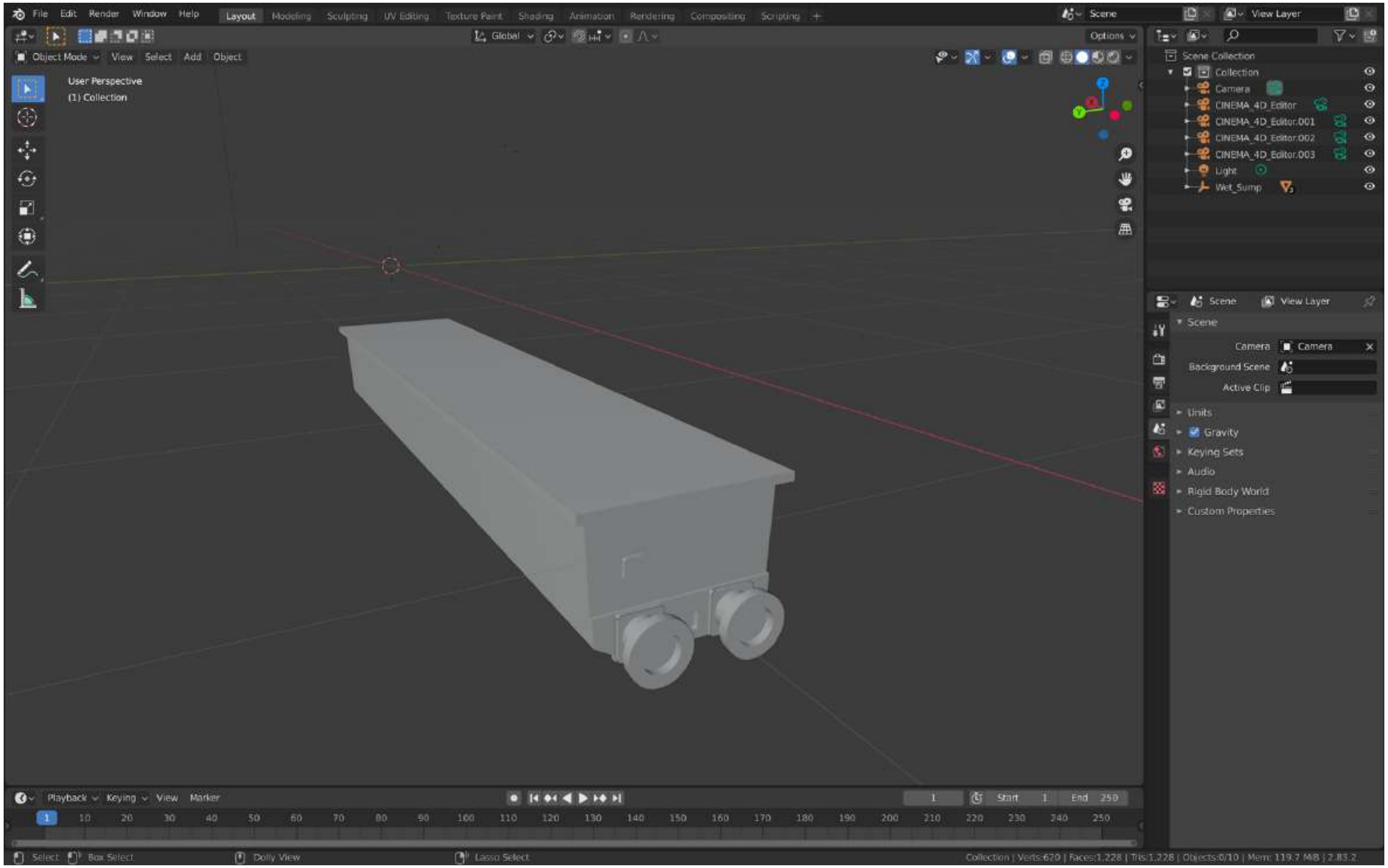

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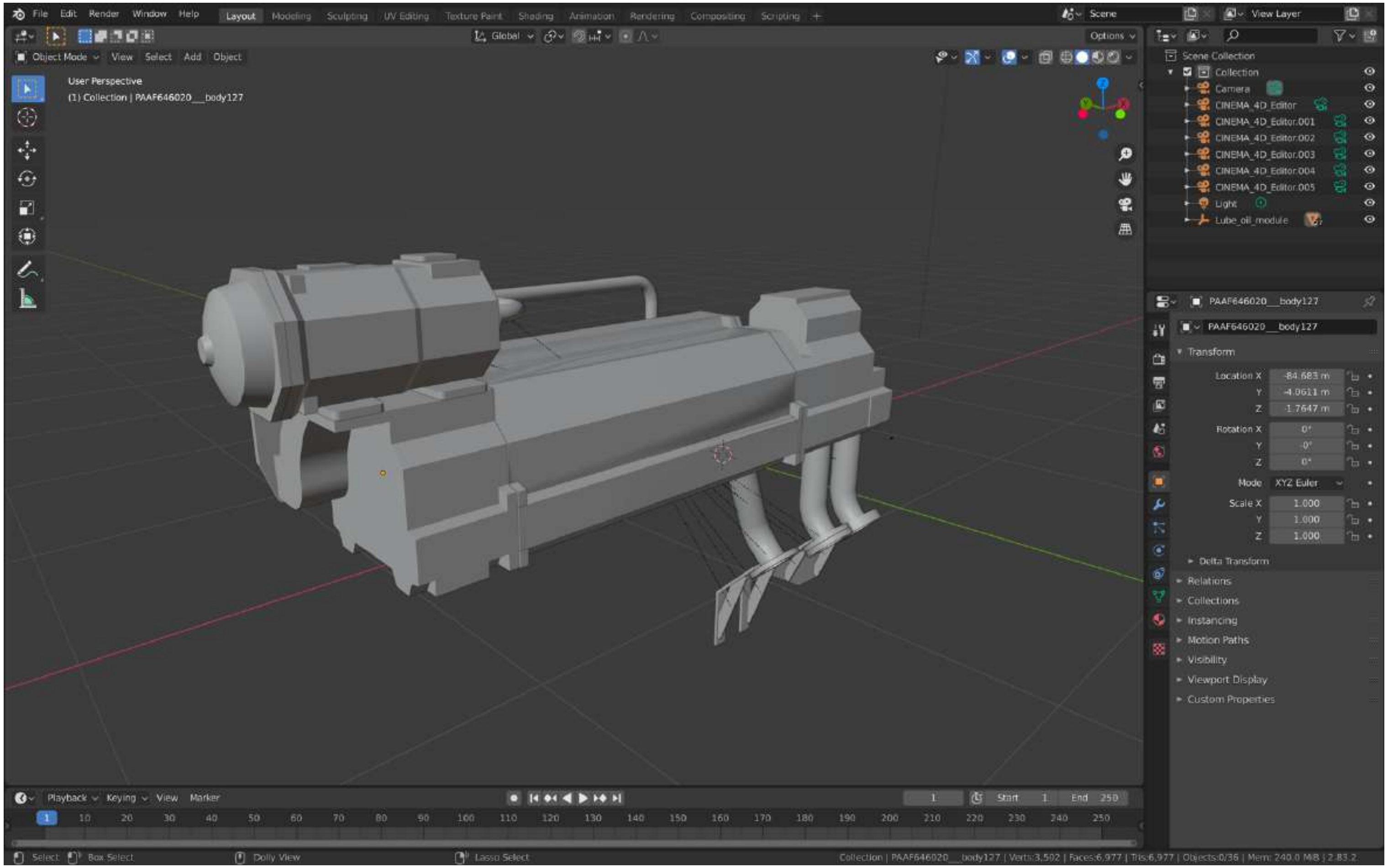

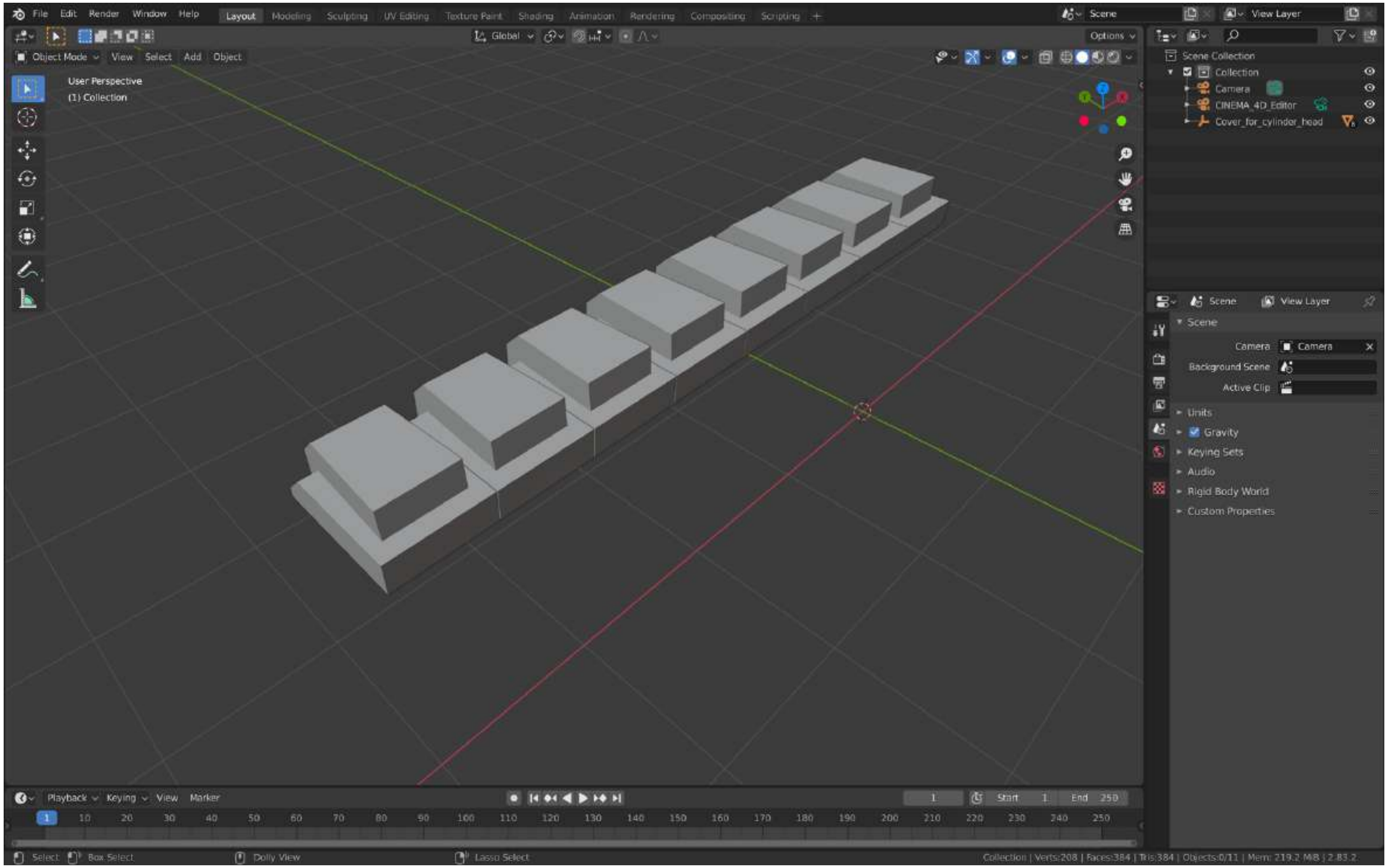
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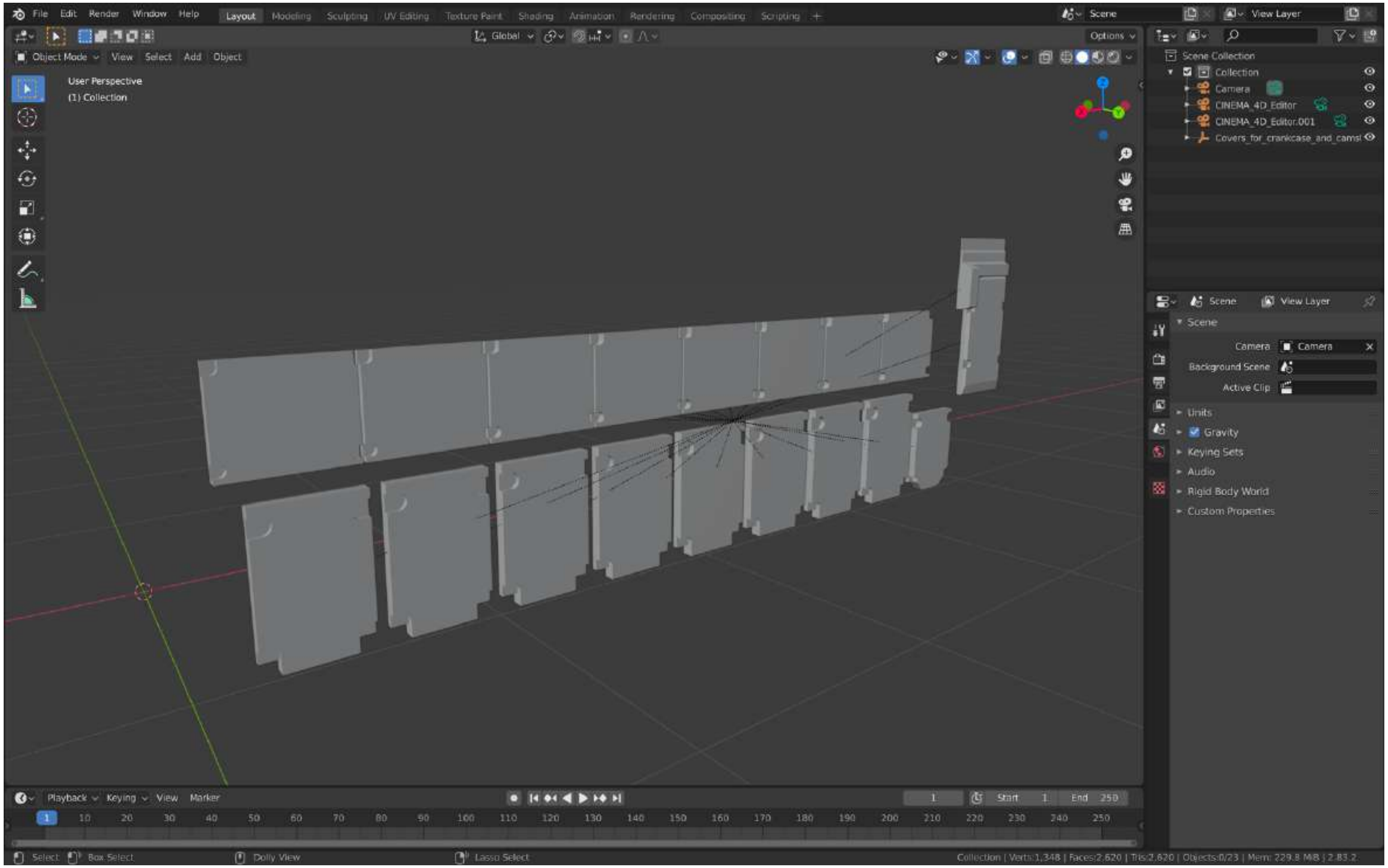
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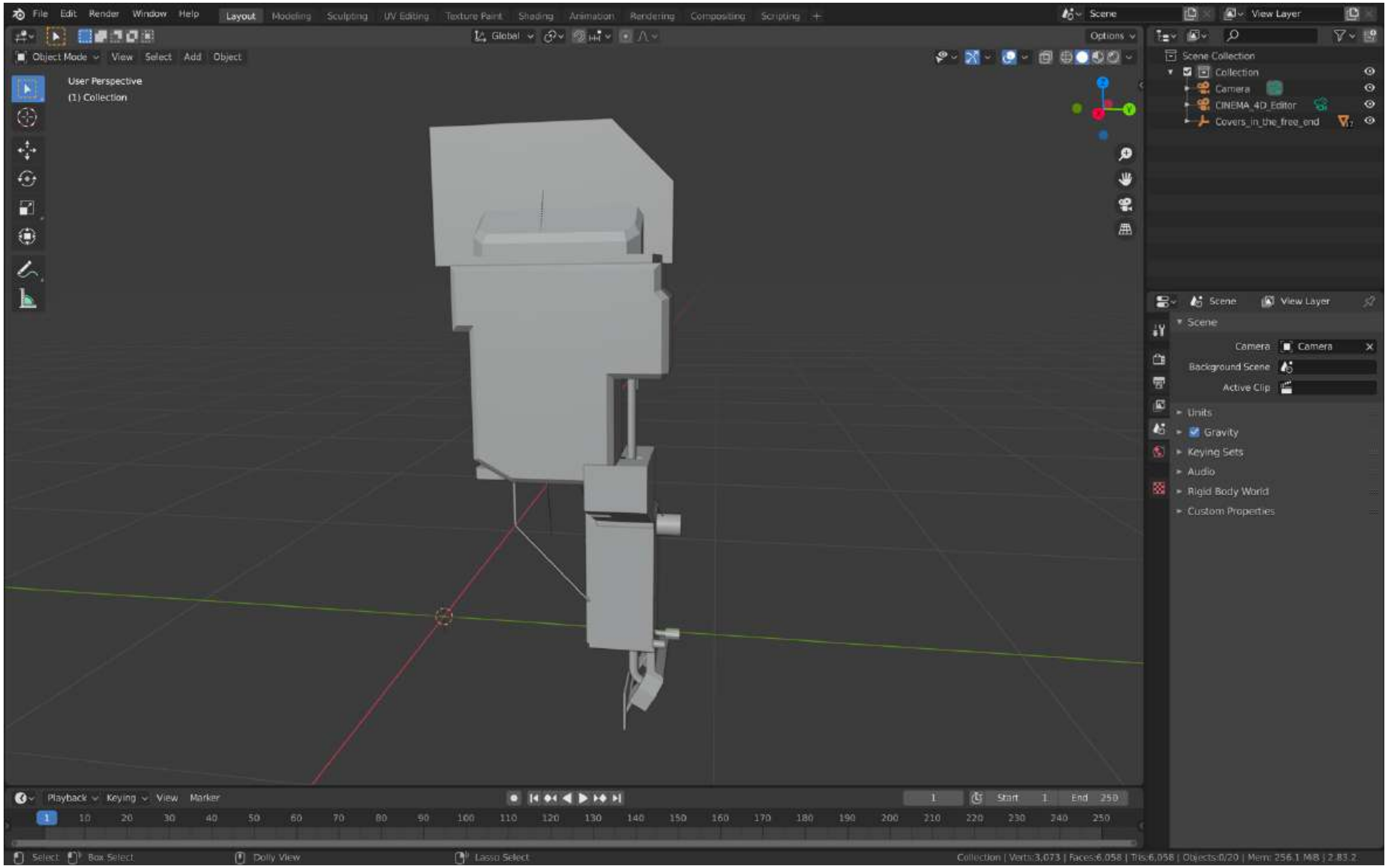
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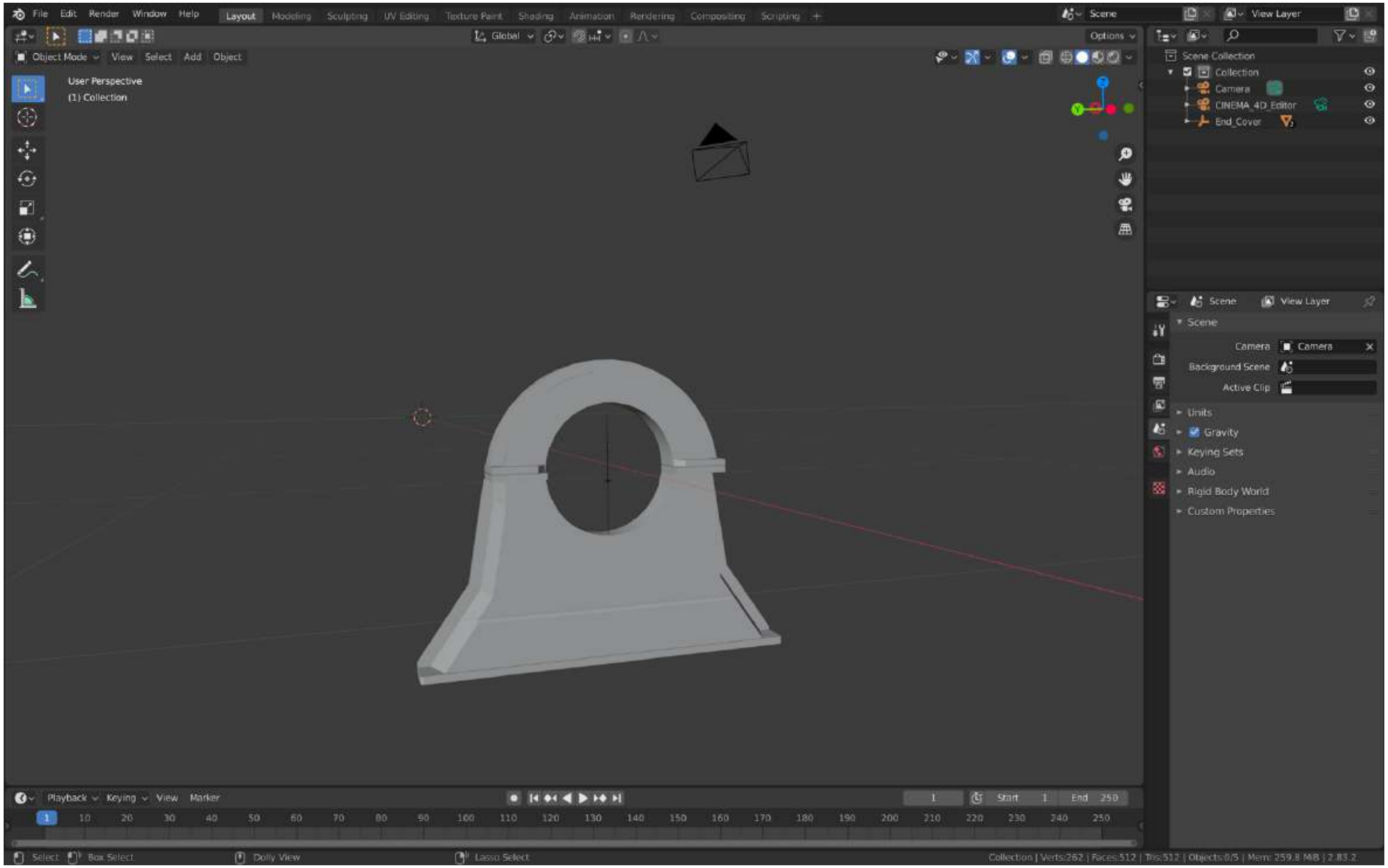
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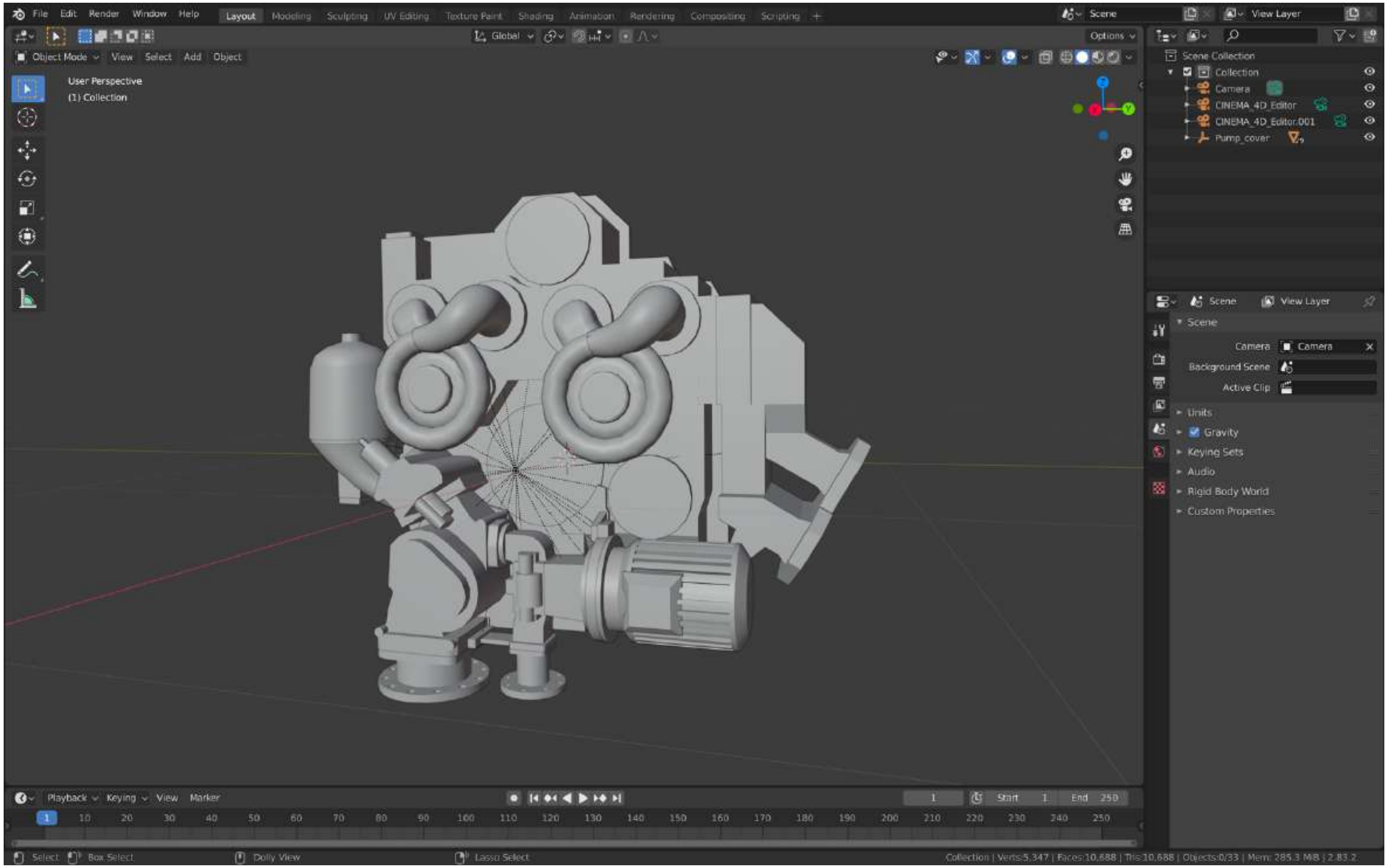
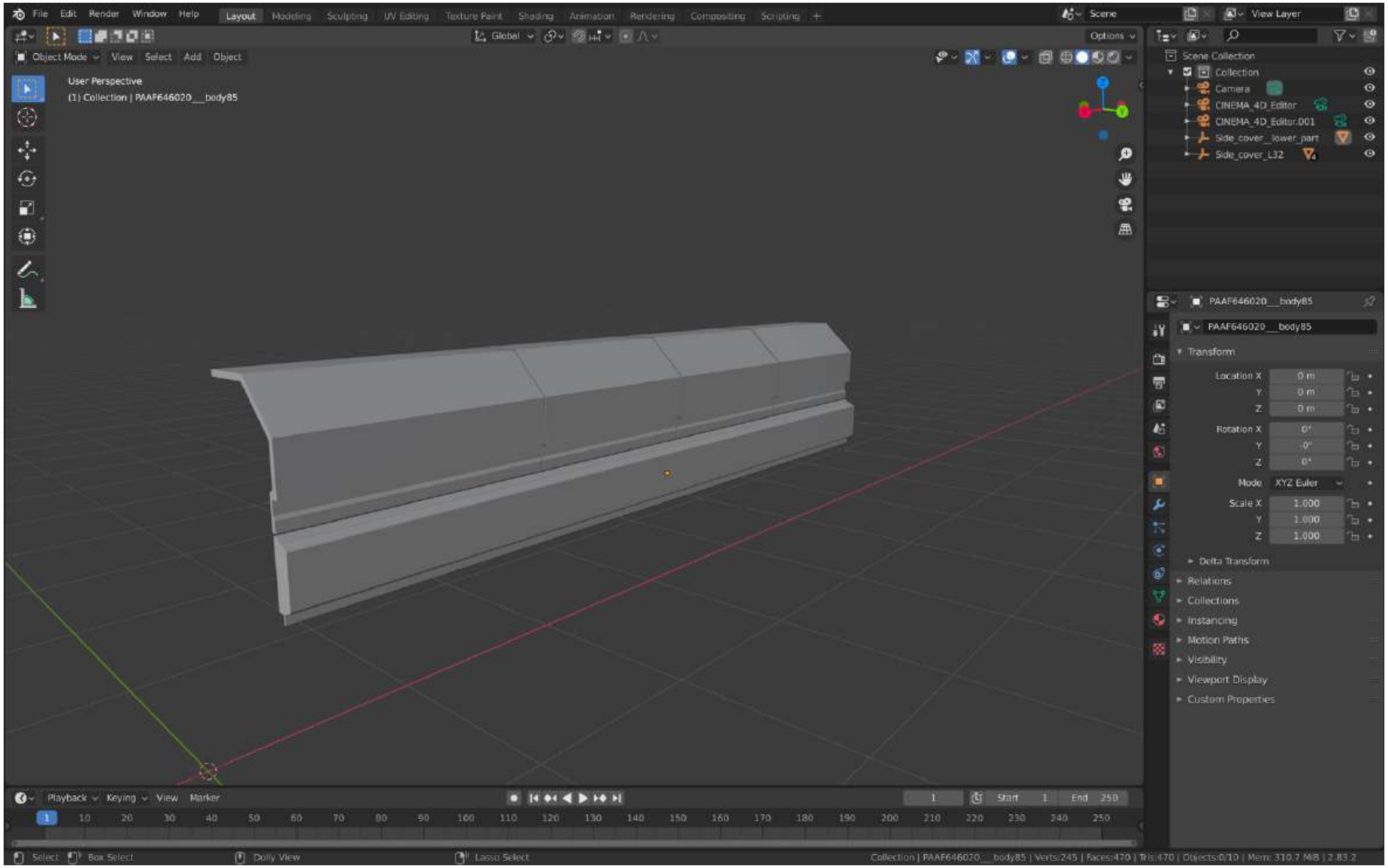
DIESEL ENGINE 3D MODEL CREATION USING BLENDER SOFTWARE





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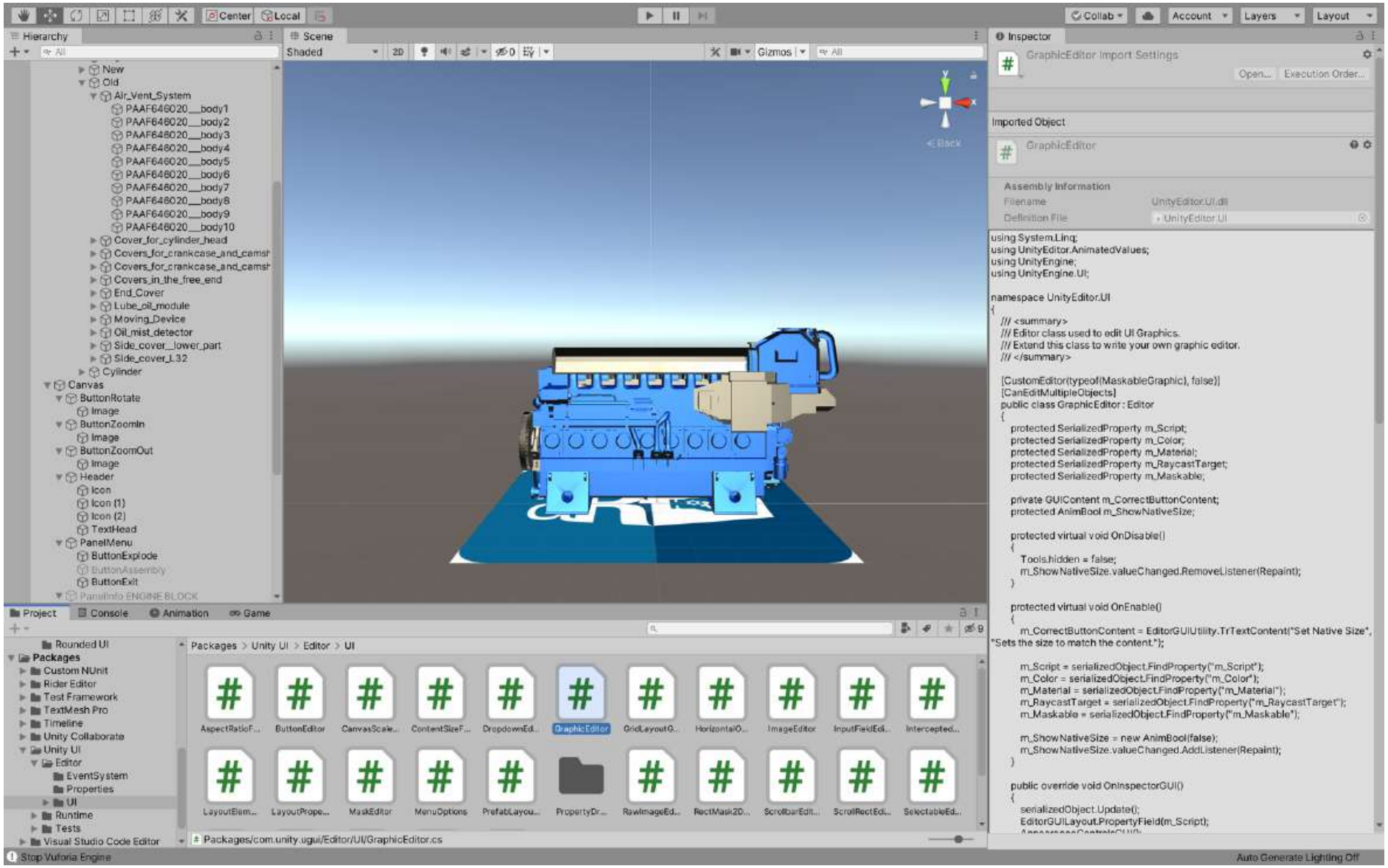
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ButtonExplode
ButtonExit
GraphicEditor Import Settings
Open...
Execution Order...
Imported Object
GraphicEditor
Assembly Information
Filename
UnityEditor.UI.dll
Definition File
UnityEditor.UI
using System.Linq;
using UnityEditor.AnimatedValues;
using UnityEngine;
using UnityEngine.UI;
namespace UnityEditor.UI
/// <summary>
/// Editor class used to edit UI Graphics.
/// Extend this class to write your own graphic editor.
/// </summary>
[CustomEditor(typeof(MaskableGraphic), false)]
[CanEditMultipleObjects]
public class GraphicEditor : Editor
protected SerializedProperty m_Script;
protected SerializedProperty m_Color;
protected SerializedProperty m_Material;
protected SerializedProperty m_RaycastTarget;
protected SerializedProperty m_Maskable;
private GUIContent m_CorrectButtonContent;
protected AnimBool m_ShowNativeSize;
protected virtual void OnDisable()
Tools.hidden = false;
m_ShowNativeSize.valueChanged.RemoveListener(Repaint);
protected virtual void OnEnable()
m_CorrectButtonContent = EditorGUIUtility.TrTextContent("Set Native Size", "Sets the size to match the content.");
m_Script = serializedObject.FindProperty("m_Script");
m_Color = serializedObject.FindProperty("m_Color");
m_Material = serializedObject.FindProperty("m_Material");
m_RaycastTarget = serializedObject.FindProperty("m_RaycastTarget");
m_Maskable = serializedObject.FindProperty("m_Maskable");
m_ShowNativeSize = new AnimBool(false);
m_ShowNativeSize.valueChanged.AddListener(Repaint);
public override void OnInspectorGUI()
serializedObject.Update();
EditorGUILayout.PropertyField(m_Script);
Project
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Rider Editor
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Timeline
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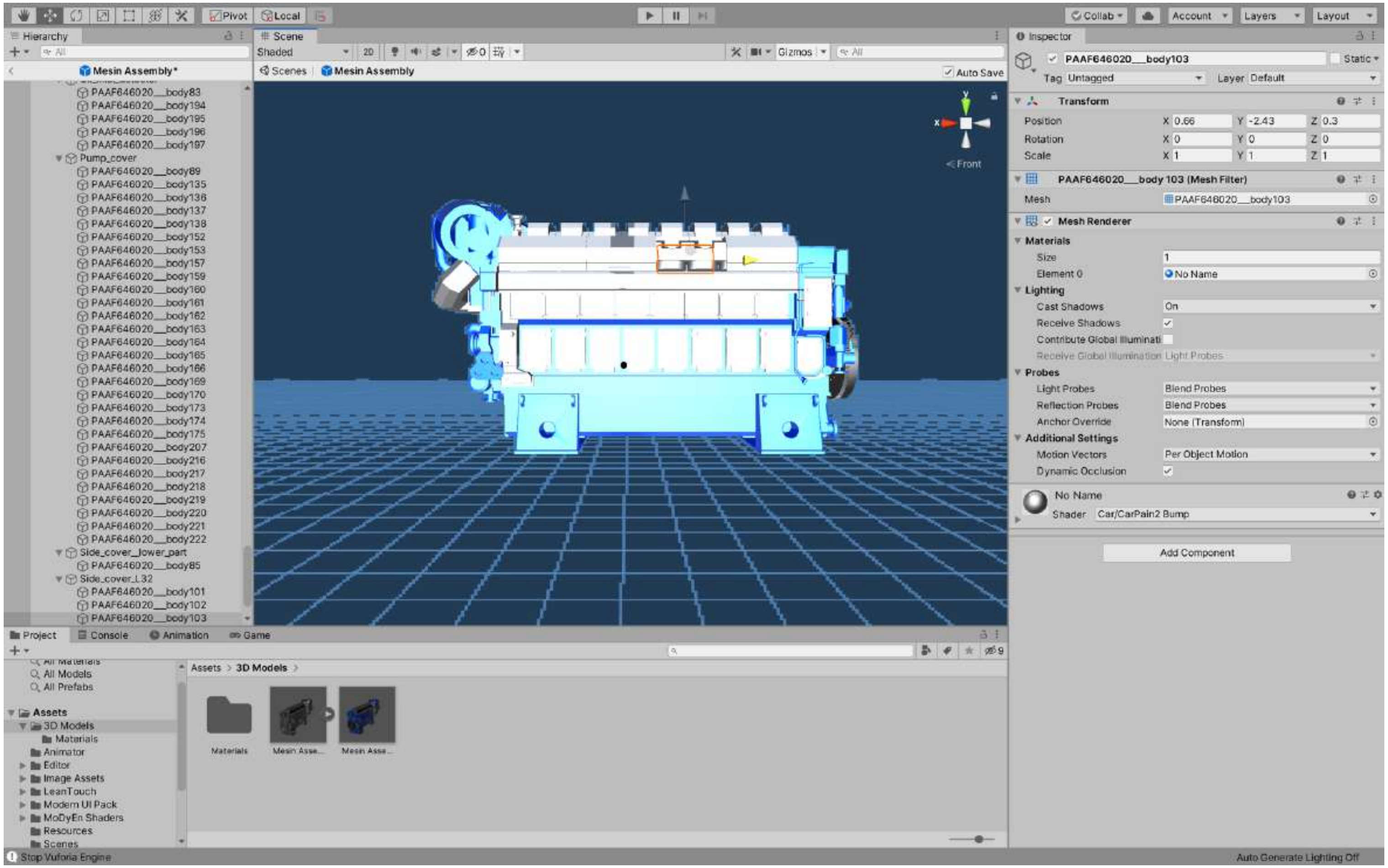
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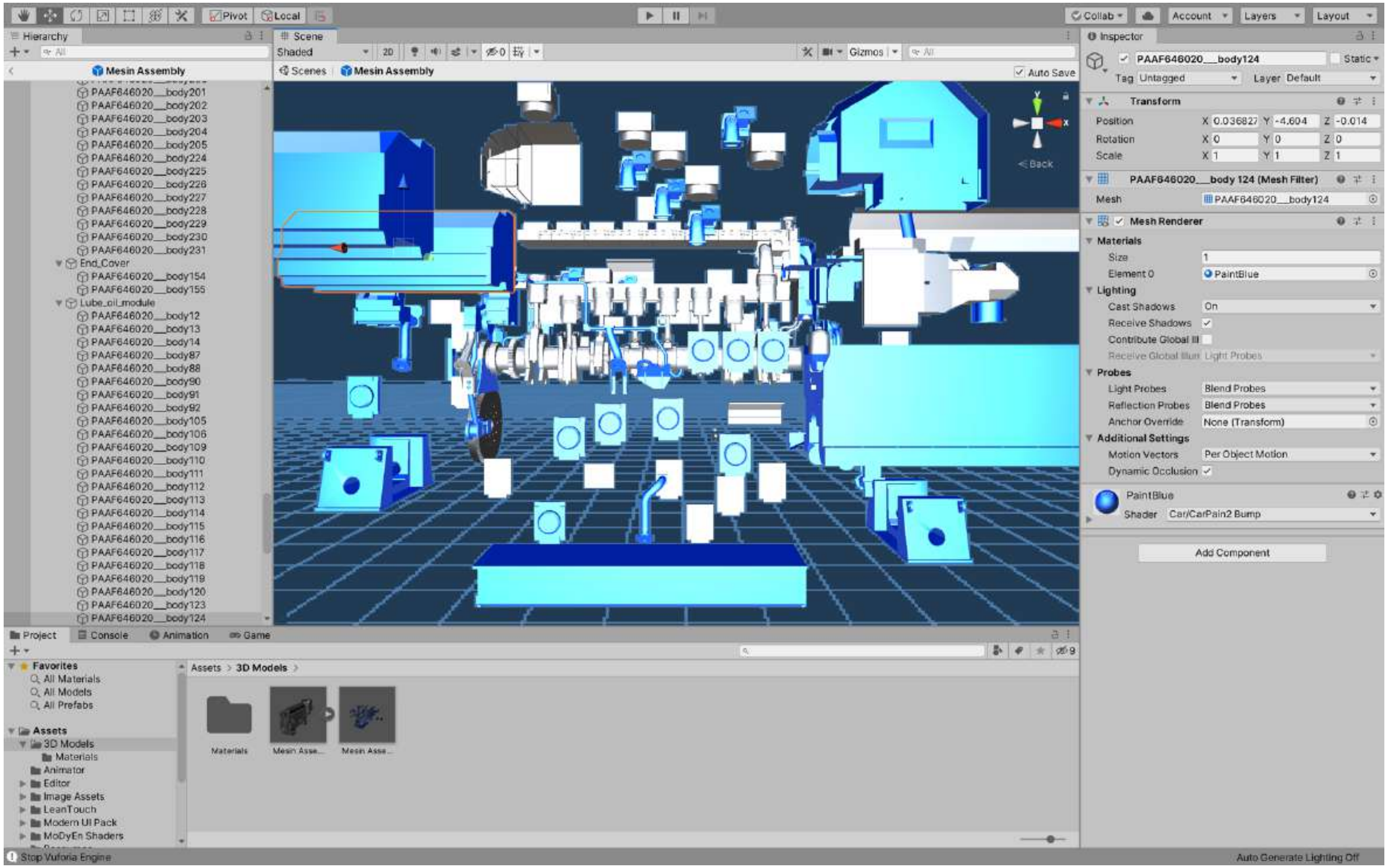
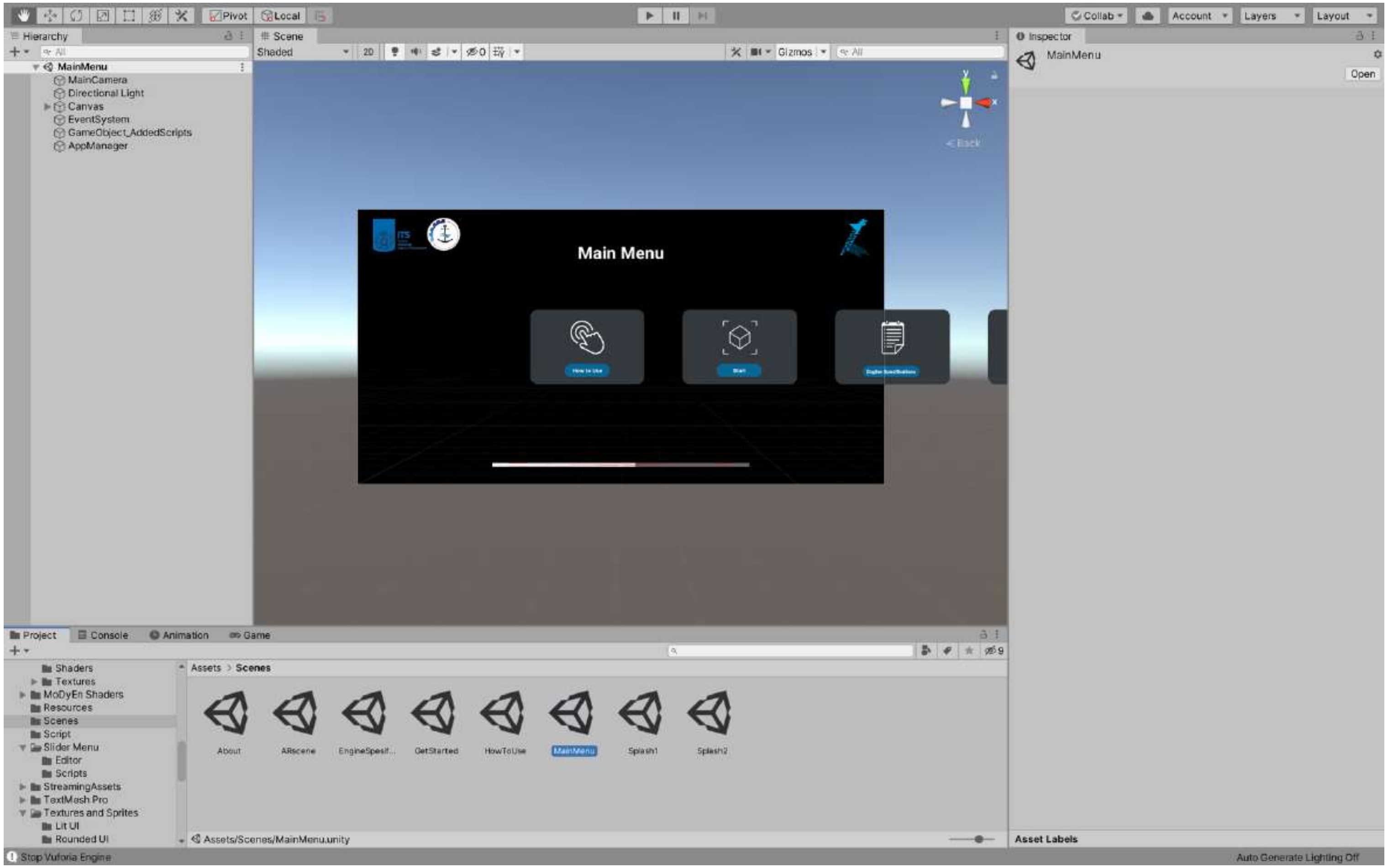
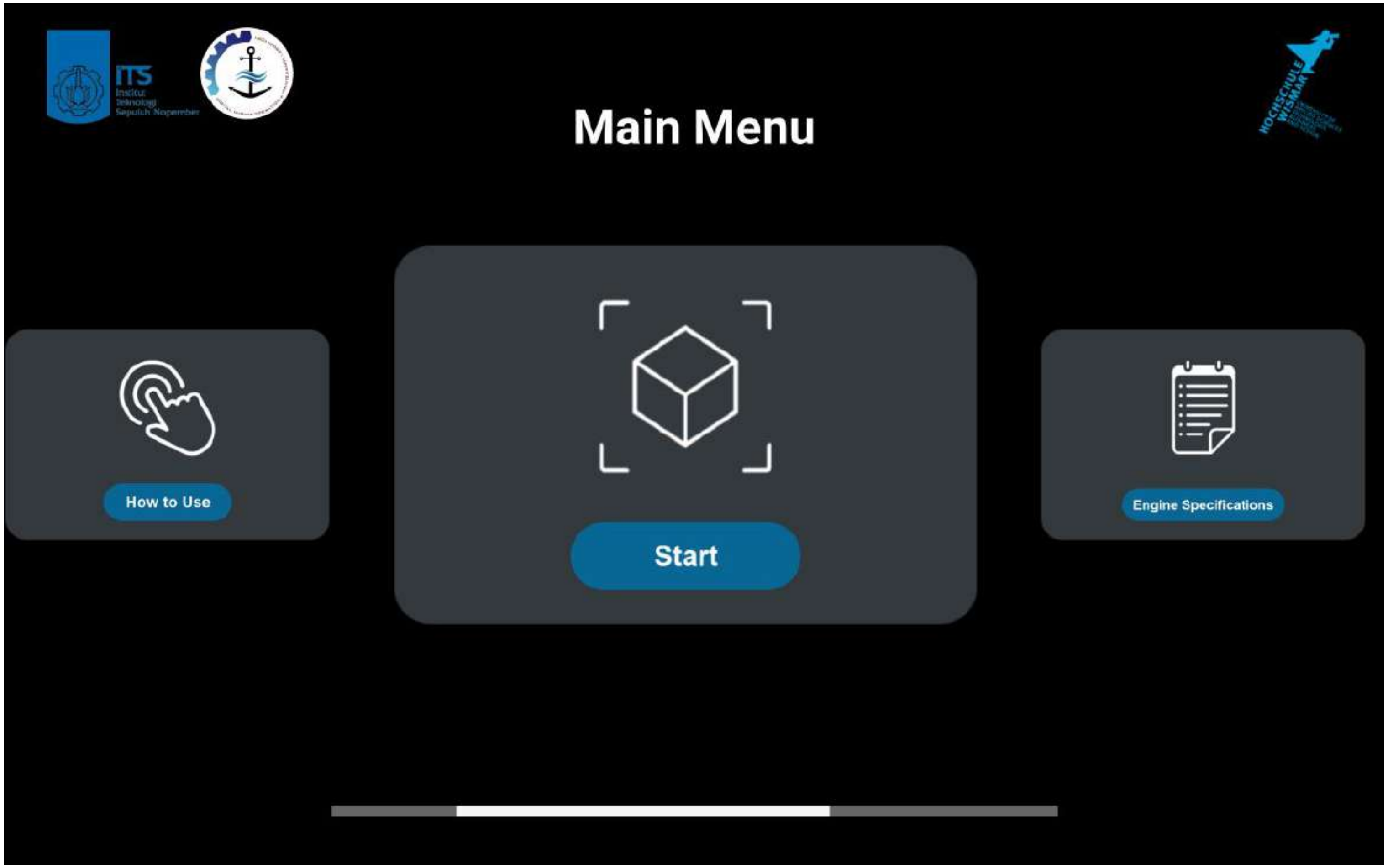
DIESEL AR APPLICATION DEVELOPMENT USING UNITY3D SOFTWARE



DIESEL AR APPLICATION DEVELOPMENT USING UNITY3D SOFTWARE



DIESEL AR APPLICATION USER INTERFACE



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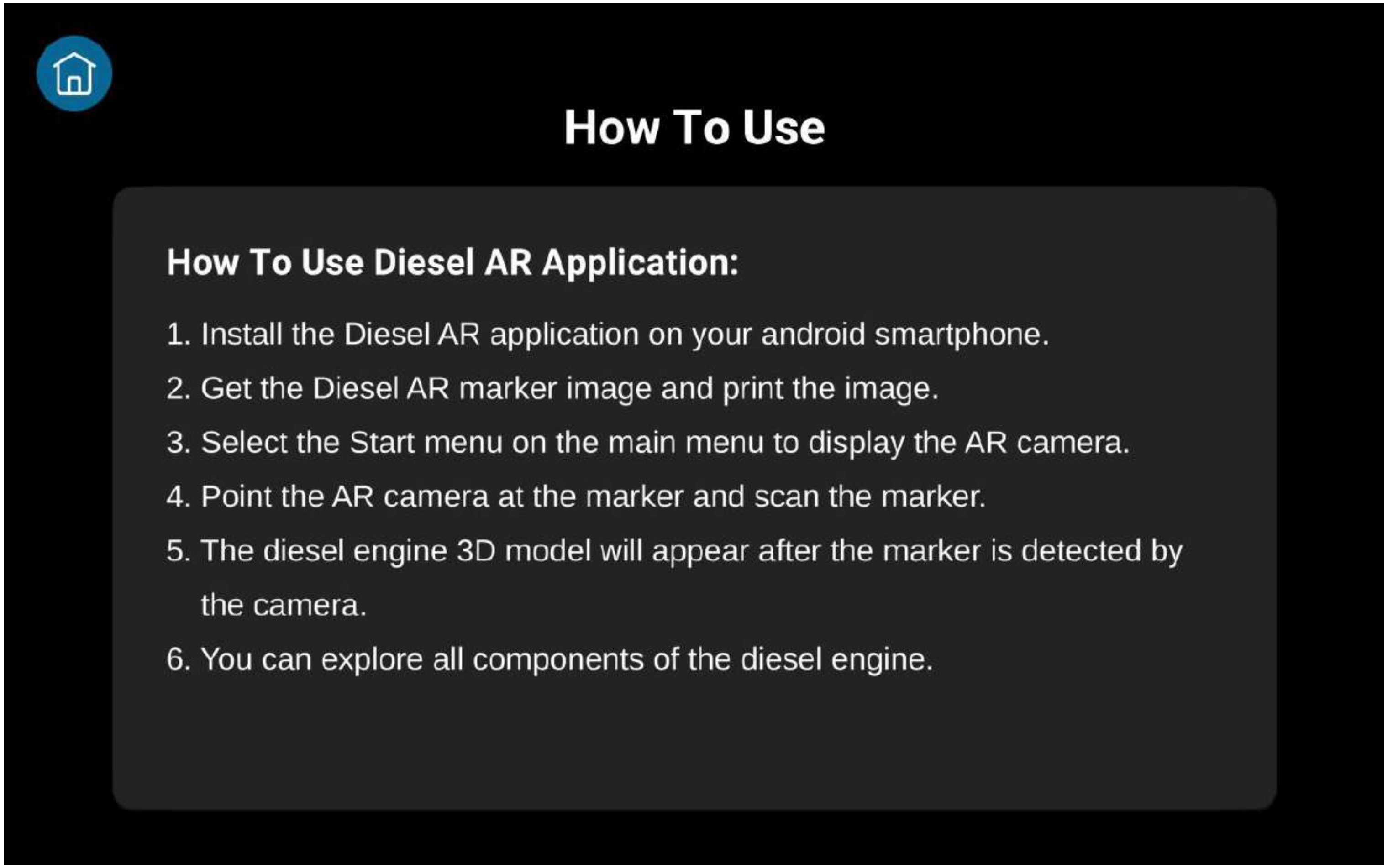
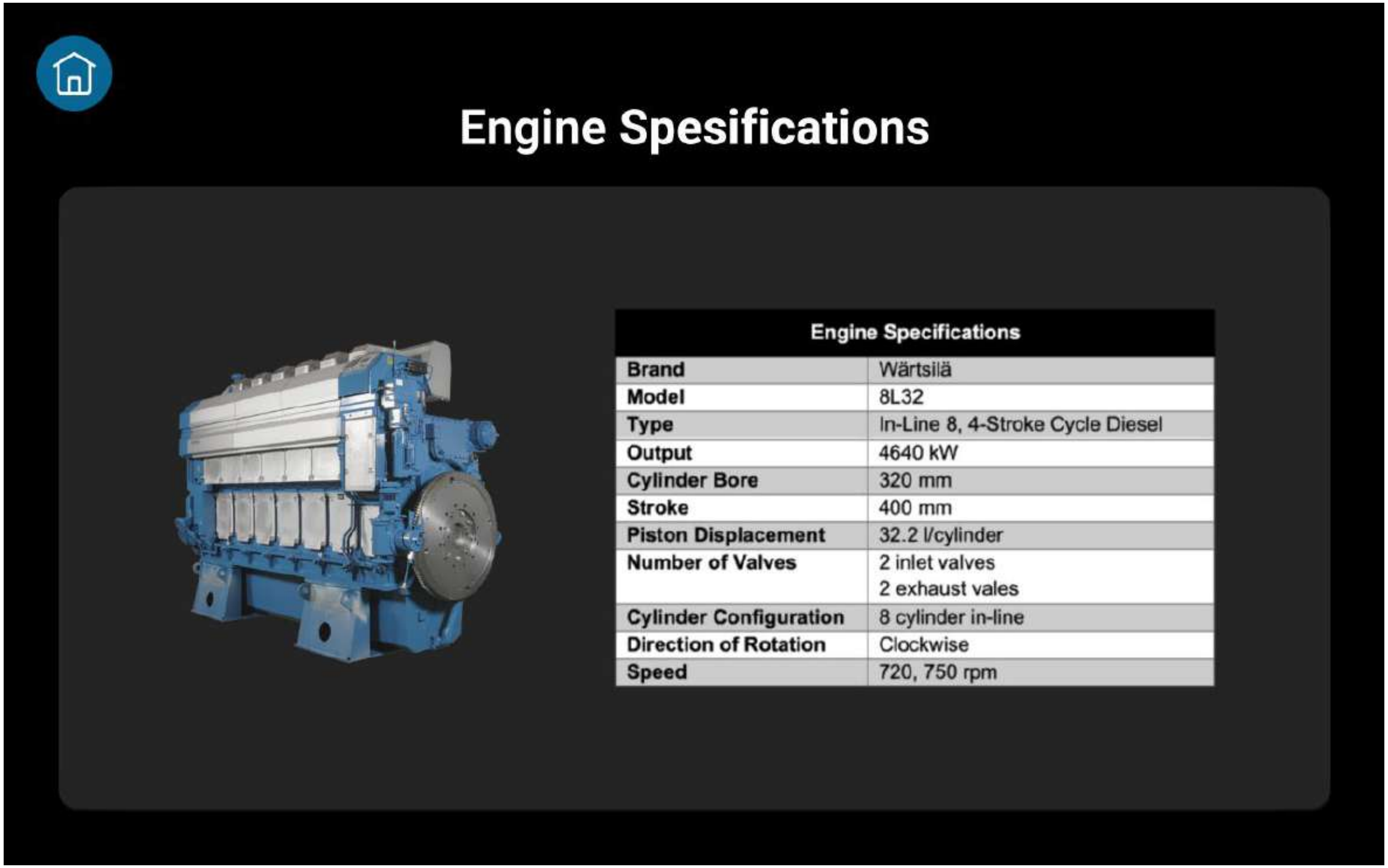
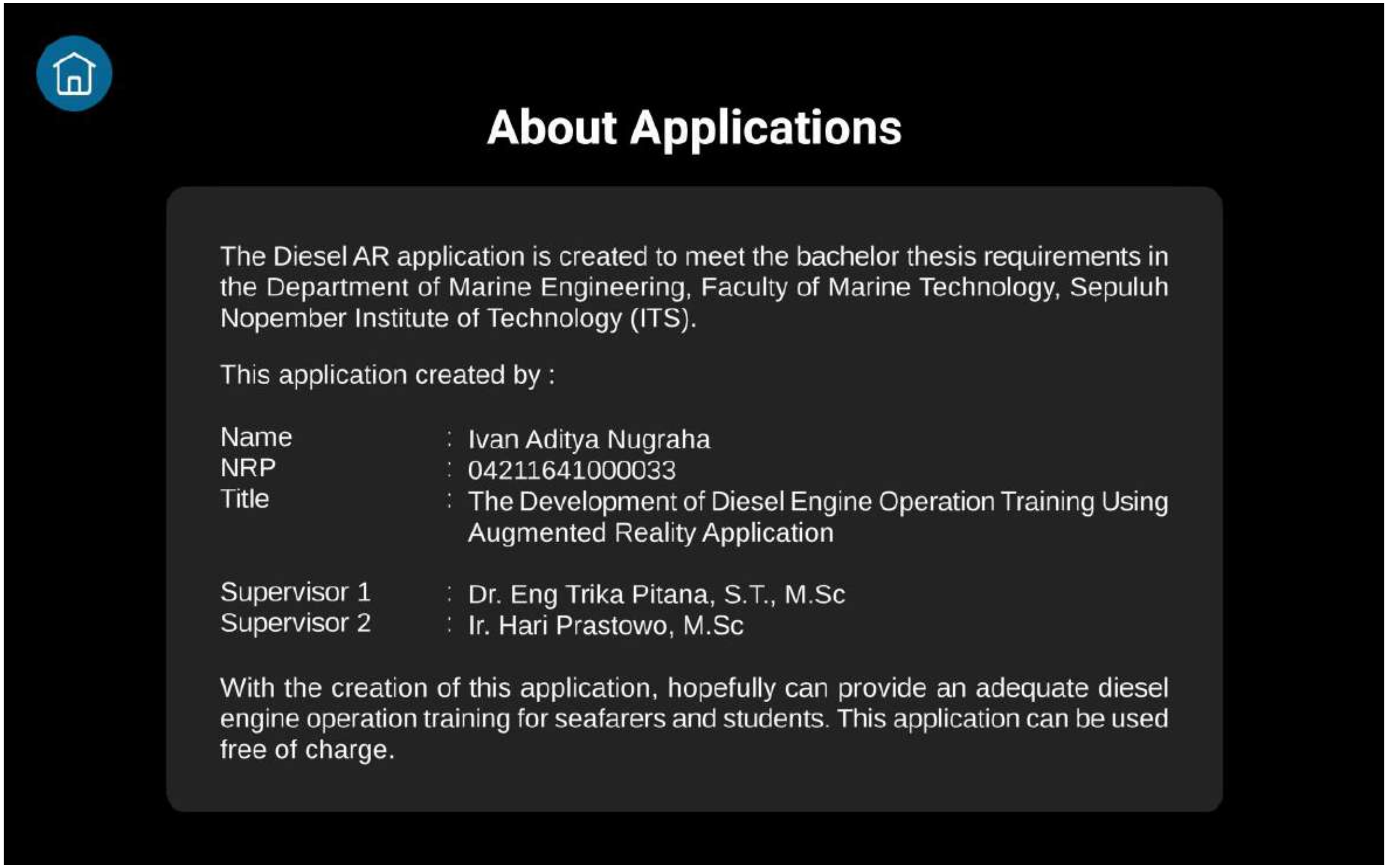




Engine Specifications	
Brand	Wärtsilä
Model	8L32
Type	In-Line 8, 4-Stroke Cycle Diesel
Output	4640 kW
Cylinder Bore	320 mm
Stroke	400 mm
Piston Displacement	32.2 l/cylinder
Number of Valves	2 inlet valves 2 exhaust vales
Cylinder Configuration	8 cylinder in-line
Direction of Rotation	Clockwise
Speed	720, 750 rpm

DIESEL AR APPLICATION USER INTERFACE



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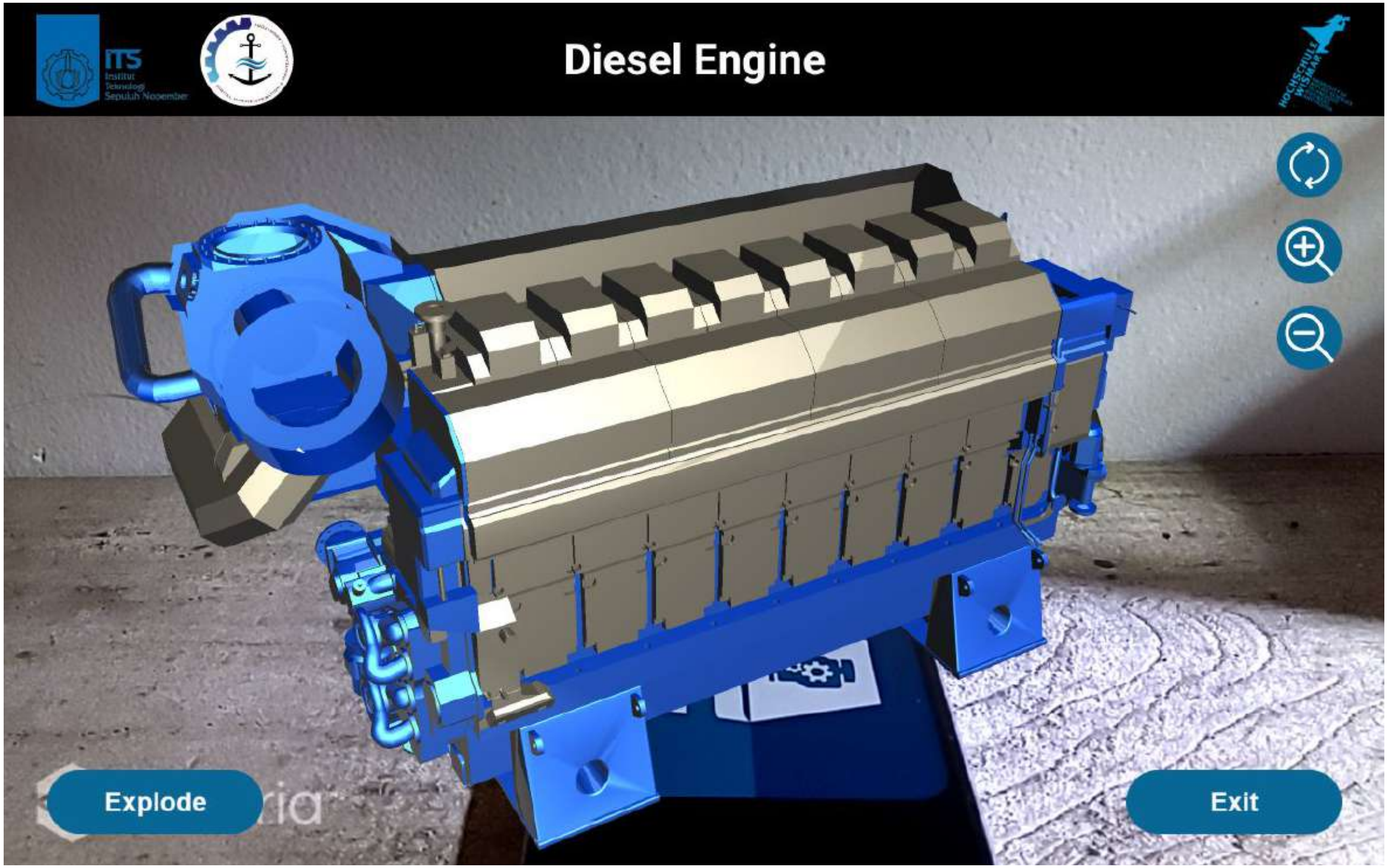

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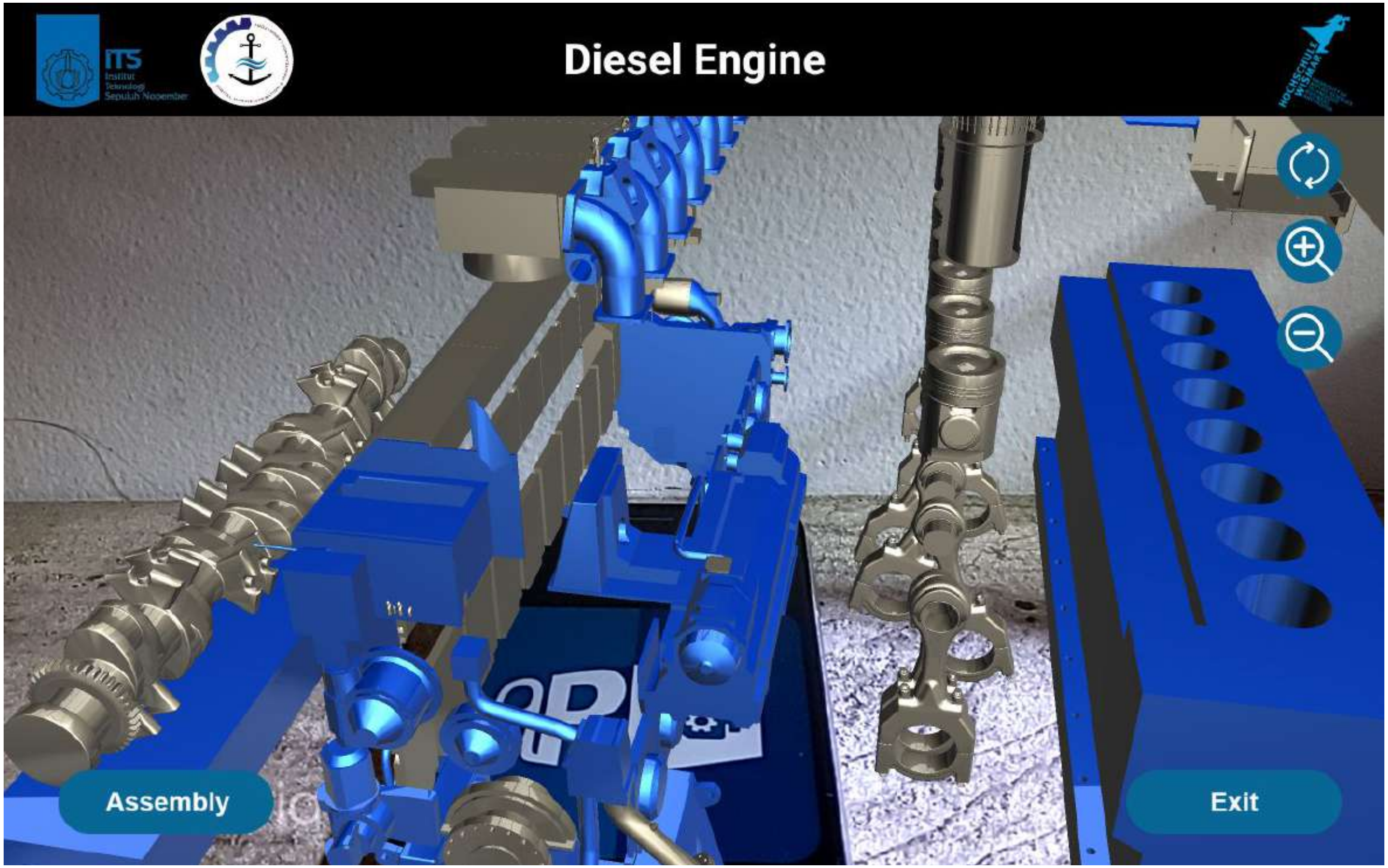

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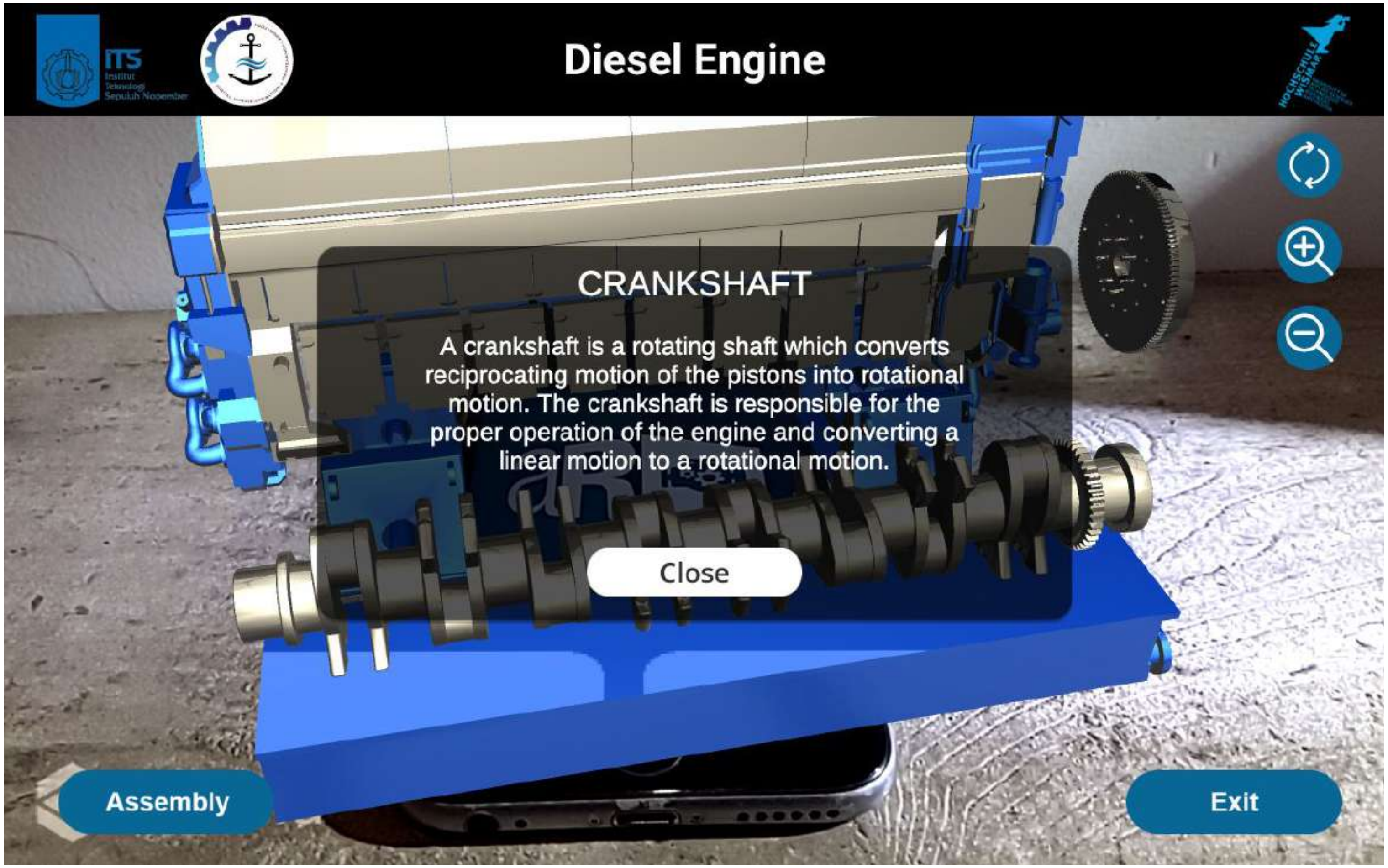

DIESEL AR APPLICATION MARKER

AUTHOR BIOGRAPHY

The author's name is Ivan Aditya Nugraha, born on 14th June 1998 in Klaten, Central Java, Indonesia. Author is the youngest child from 3 siblings. Author is derived from a family with father named Sukirno and mother named Wening Rahayu. The author was raised in the Klaten City, Central Java. The author had formal studies at SD Negeri 1 Ceper (2004-2010), SMP Negeri 2 Klaten (2010-2013), SMA Negeri 1 Klaten (2013-2016). And after that, the author went to Surabaya to continue the study at Department of Marine Engineering, Double Degree Program with Hochschule Wismar, Faculty of Marine Engineering, Sepuluh Nopember Institute of Technology (ITS) specialized in Digital Marine Operation and Maintenance. During the study period, the author did co-curricular activities such as Society of Petroleum Engineers (SPE ITS) Student Chapter, and ITS Marine Solar Boat Team. The author also got merit-based scholarship from American Bureau of Shipping (ABS) in 2018. The author has work experiences as an Engineering Intern at PT. Industri Kapal Indonesia in 2018 and as an Junior Superintendent Intern at PT. Pertamina Trans Kontinental in 2019. For further discussion and suggestion regarding this research, the author can be reached through email states as below.

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ivanadityan@gmail.com