BACHELOR THESIS & COLLOQUIUM – ME 184841

THE APPLICATION OF VIRTUAL REALITY TECHNOLOGY FOR INSPECTION TRAINING IN COMPLIANCE WITH MARITIME LABOUR CONVENTION, 2006

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DOUBLE DEGREE PROGRAM OF
DEPARTMENT OF MARINE ENGINEERING
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SKRIPSI – ME 184841

PENGEMBANGNAN PELATIHAN INSPEKSI TERKAIT MARITIME LABOUR CONVENTION, 2006 DENGAN MENGGUNAKAN APLIKASI REALITAS VIRTUAL

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SURABAYA
2020

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APPROVAL SHEET

THE APPLICATION OF VIRTUAL REALITY TECHNOLOGY FOR INSPECTION TRAINING IN COMPLIANCE WITH MARITIME LABOUR CONVENTION, 2006

BACHELOR THESIS

Submitted to Comply One of the Requirement to Obtain a
Bachelor's Degree in Engineering
at
Laboratory of Digital Marine Operation and Maintenance (DMOM)
Bachelor Program Department of Marine Engineering
Sepuluh Nopember Institute of Technology

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APPROVAL FORM

THE APPLICATION OF VIRTUAL REALITY TECHNOLOGY FOR INSPECTION TRAINING IN COMPLIANCE WITH MARITIME LABOUR CONVENTION, 2006

BACHELOR THESIS

Submitted in fulfilment of requirement for the degree of Bachelor Engineering

at

Digital Marine Operation and Maintenance (DMOM)

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APPROVAL SHEET

THE APPLICATION OF VIRTUAL REALITY TECHNOLOGY FOR INSPECTION TRAINING IN COMPLIANCE WITH MARITIME LABOUR CONVENTION, 2006

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DECLARATION OF HONOR

I hereby who signed below declare that:

This final project has been written and developed independently without any plagiarism act. All contents and ideas drawn directly from internal and external sources are indicated such as cited sources, literatures and other professional sources.

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Final Project Title	:	The Application of Virtual Reality Technology For Inspection Training In Compliance With Maritime Labour Convention, 2006
Departement	:	Marine Engineering

If there is plagiarism act in the future, I will fully be responsible and receive the penalty given by ITS according to the regulation applied.

Surabaya, July 2020

Jody Muhammad Ezananda

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PREFACE

Praise be to Allah, the Lord of the Worlds, for His grace and mercy have brought us to the perfect condition of health and send us the best of His creatures to support and give a lot of positive energy in order to finish this Undergraduate Final Project or Bachelor Thesis. May the peace and blessings of Allah be showered on His beloved Prophet Muhammad and his followers.

During the accomplishment of this final project, we would like to thank every parties who have been very helpful, and giving us assistance and support so that we are able to complete this project very well. We would like to give the most sincere thanks to:

1. Eko Wahyu Nurhidayat and Ussa Syamsiah, our beloved parents, for the countless prayers and support this whole time, as well as Farial Ezananda and Shafa Trivia Ezananda, our siblings, and Churotul ‘Ain, our beloved grandmother.
2. Dr.Eng. Trika Pitana, ST., M.Sc. and Ir. Hari Prastowo, M.Sc., our supervisor and co-supervisor respectively, for the assistance and guidance during the completion of this final project.
3. Benny Cahyono, S.T., M.T., Ph.D, as the Head of Marine Engineering Department, Ir. Dwi Priyanta, M.SE. as our academic advisor, as well as the rest of the lecturers and staffs at Marine Engineering Department of Sepuluh Nopember Institute of Technology who have taught us and helped us during our 4 years in DDME.
4. Aqnil Putra Mahdali, Ar-Rosyid Hidayatullah, Choirul Fadholani, and Qobus Tsaqif for being massively helpful to this final project.
5. Fellow campus mates, DMOM Laboratory Members, P-56 DDME 2016, and the whole Voyage ’16 family.
6. OMDO GAMING, The Flatters, Volkgaze, SAIMS 5th, Omah, and many other close friends and families whom we cannot mention one by one, plus Rina Sawayama, Tyler, the Creator, LCD Soundsystem, Interpol, Perfume Genius, Taylor Swift, Radiohead and The Strokes whose albums had kept us accompanied on the nights we worked on this final project.

Since this work is still far from perfect, we do appreciate every advice, suggestion, and idea from any party for the sake of this bachelor thesis correction and improvement in the future. By the completion of this bachelor thesis, we hope this thesis will be beneficial for other parties who are going to conduct similar research.

Surabaya, July 2020

Jody Muhammad Ezananda

THE APPLICATION OF VIRTUAL REALITY TECHNOLOGY FOR INSPECTION TRAINING IN COMPLIANCE WITH MARITIME LABOUR CONVENTION, 2006

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ABSTRACT

One of the developments in the maritime sector include applications of advanced computer graphics technology. Ranging from marketing and design over manufacturing support to familiarization, training and maintenance assistance for marine survey, there is no phase in the lifecycle of a ship or seaborne structure that would not profit from 3D modelling, simulation, virtual/augmented reality or computer vision. Applications of Virtual Reality (VR) have and continue to increase over the last couple of years. This trend is expected to continue in the future with the advancement of technology in areas like computer graphics, computer vision, controls, image processing and other technology-affiliated components. VR has found vast applications in many fields due to its characteristics and the benefits it provides in solving complex real-world problems. Therefore, the use of Virtual Reality as a means of education is felt necessary to support the sustainability of the maritime industry, as well as empowering human and economic resources in it. In this case, what will be used as research material specifically is the application of Virtual Reality technology as a means of education and inspection regarding the 2006's Maritime Labour Convention, which is one of the mandatory (statutory) aspects that becomes a checklist in the building and operation of a ship. The study utilizes an actual container ship MV. Meratus Benoa and its compartments to become objects of reference for the making of ship virtual environment. The process of the creation is to convert real objects into 3D assets using Blender software, and later develop it into a whole package of virtual reality application which is developed using Unity software. Based on the user assessment, that involves around 10 respondents (7 of which are marine students or trainee) it can be concluded that this Virtual Reality Application for MLC, 2006 Inspection Training has scored 331 out of 400 which is in the excellent category.

Keywords: Virtual Reality, Inspection Training, Maritime Labour Convention 2006, Ship Crew, Ship Accommodation and Facilities, 3D Modelling

PENGEMBANGNAN PELATIHAN INSPEKSI TERKAIT MARITIME LABOUR CONVENTION, 2006 DENGAN MENGGUNAKAN APLIKASI REALITAS VIRTUAL

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ABSTRAK

Salah satu perkembangan di bidang kelautan antara lain penerapan teknologi grafik komputer yang canggih. Mulai dari pemasaran dan desain melalui dukungan manufaktur hingga pengenalan, pelatihan, dan bantuan pemeliharaan untuk survei kelautan, tidak ada fase dalam siklus hidup kapal atau struktur pelayaran yang tidak akan mendapat keuntungan dari pemodelan 3D, simulasi, realitas virtual / augmented atau visi komputer. Aplikasi Virtual Reality (VR) telah dan terus meningkat selama beberapa tahun terakhir. VR telah menemukan aplikasi yang luas di banyak bidang karena karakteristiknya dan manfaat yang diberikannya dalam memecahkan masalah dunia nyata yang kompleks. Oleh karena itu, pemanfaatan Virtual Reality sebagai sarana edukasi dirasa perlu untuk mendukung keberlangsungan industri maritim, serta pemberdayaan sumber daya manusia dan ekonomi di dalamnya. Dalam hal ini, yang akan dijadikan sebagai bahan penelitian secara spesifik adalah penerapan teknologi Virtual Reality sebagai sarana edukasi dan inspeksi terkait Konvensi Perburuhan Maritim tahun 2006 yang merupakan salah satu aspek wajib (regulasi / aturan) yang menjadi checklist di dalam perancangan dan pengoperasian kapal. Studi ini didasarkan pada kapal kontainer nyata yaitu MV. Meratus Benoa beserta kompartemen-kompartemennya yang menjadi objek acuan dalam pembuatan lingkungan virtual kapal. Proses pembuatannya adalah mengubah objek nyata menjadi aset 3D menggunakan software Blender, kemudian mengembangkannya menjadi satu paket aplikasi virtual reality yang dikembangkan menggunakan software Unity. Berdasarkan penilaian pengguna yang melibatkan sekitar 10 responden (7 di antaranya adalah mahasiswa atau peserta pelatihan kelautan) dapat disimpulkan bahwa Aplikasi Virtual Reality untuk MLC Pelatihan Inspeksi 2006 ini mendapatkan skor 331 dari 400 yang berada pada kategori sangat baik.

Kata Kunci: Realitas Maya, Pelatihan Inspeksi, Maritime Labour Convention 2006, Kru Kapal, Fasilitas dan Akomodasi Kapal, Permodelan 3D

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CHAPTER I
INTRODUCTION

1.1 Background Knowledge

The advancement of innovation has made it conceivable to upgrade the improvement in marine industry. Indonesia is one nation that has an incredible sea potential. Indonesia comprise of a gathering of islands with a coastline with long until 95,000 km. With existing topographical conditions, Indonesia has an incredible potential for marine industry. Indonesia has area of the economy that is not dependent on the territory, yet in addition in sea field and make oceanic based economy keeps on developing in Indonesia and improve the advancement of different enterprises. The business which is firmly identified with ocean transport are the port business, multi-modular vehicle, an insurance agency, shipbuilding industry and that is just the beginning. The business has connection one another and become together.

One of the developments in the maritime sector applications of advanced computer graphics technology. Ranging from marketing and design over manufacturing support to familiarization, training and maintenance assistance for marine survey, there is no phase in the lifecycle of a ship or seaborne structure that would not profit from 3D modelling, simulation, virtual/augmented reality or computer vision.

Applications of Virtual Reality (VR) have and continue to increase over the last couple of years. This is partly due to its usefulness in many fields and as a result of the attention given to it by the media. This trend is expected to continue in the future with the advancement of technology in areas like computer graphics, computer vision, controls, image processing and other technology-affiliated components. VR has found vast applications in many fields due to its characteristics and the benefits it provides in solving complex real-world problems. Some of the application areas include: Architecture, Arts, Business, Design and Planning, Education and Training, Entertainment, Manufacturing, Medical and Scientific Visualization. Benefits of using Virtual Reality for marketing and commercial purposes are evident. That is why Virtual Reality tools are having a great reception in sales and marketing activities. Thanks to the wide range of possibilities available in the market, from small and portable solutions to big and on-demand solutions, the present and future applications of Virtual Reality is higher than we can imagine.

Maritime industry is affected by a global and extremely competitive environment. All processes and systems have to be adapted to this challenging scenario, making special efforts in innovation and applying the most advanced technology available in the market. The Virtual Reality application to maritime is not new, but it is more extended now thanks to the important improvements in software and hardware. From a user point of view, it is possible now to find a wide range of solutions to meet the most demanding requirements, to achieve measurable results, in terms of efficiency and costs.

Not only for design and production needs, the use of Virtual Reality is also very useful for continuing education in the maritime sector. For example, the use of Virtual Reality can be used as a means of learning, training, or simulations for students and officers who are carrying out education in the maritime sector, whether in the fields of engineering or shipping, and this is not limited to the general public.

Therefore, the use of Virtual Reality as a means of education is felt necessary to support the sustainability of the maritime industry, as well as empowering human and economic resources in it. In this case, what will be used as research material specifically is the application of Virtual Reality technology as a means of education and inspection regarding the 2006 Maritime Labor Convention, which is one of the mandatory (statutory) aspects that becomes a checklist in the building and operation of a ship.

1.2 Research Problems

Based on background mentioned above, the research problems for this final project is:

a. How to apply Virtual Reality technology as a training media for inspection in compliance with Maritime Labour Convention, 2006

1.3 Research Limitations

The research limitations for this final projects are:

a. In this research using Unity3D to build simulation in Virtual Reality Application.
b. The Virtual Reality Program will give simulation training of Maritime Labour Convetion checklist within a ship environment.

1.4 Research Objectives

The research objective of this final project is:

a. To build simulation of Maritime Labour Convention 2006 inspection in the form of Virtual Reality Mobile Application

1.5 Research Benefits

The benefits that is expected from this final project is:

a. Provide a unique and effective way to learn for students/surveyor, because Virtual Reality technology has advanced incentive in circumstances where investigation of situations or communications with objects or individuals is unimaginable or badly arranged, or where a domain can just exist in PC created environment. Virtual Reality is additionally important when the experience of really making a mimicked a situation and can be gotten to for preparing in any other situation and at any time.

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CHAPTER II
LITERATURE STUDY

2.1 Maritime Labour Convention

The Maritime Labour Convention 2006 (MLC) is an international agreement of the International Labour Organisation ('ILO') which sets out seafarers' rights to decent conditions of work. It is sometimes called the 'Seafarers' Bill of Rights'. It applies to all seafarers, including those with jobs in hotel and other passenger services on cruise ships and commercial yachts. In 2013 the MLC became binding law for 30 countries (Lavelle, 2013).

As of January 2019, a total of 90 countries had ratified the MLC 2006, which has resulted in more than 91% of the world's shipping fleet being regulated. For detailed information please visit the ILO website.

More than 100 pages long, the MLC 2006 sets minimum requirements for nearly every aspect of working and living conditions for seafarers including recruitment and placement practices, conditions of employment, hours of work and rest, repatriation, annual leave, payment of wages, accommodation, recreational facilities, food and catering, health protection, occupational safety and health, medical care, onshore welfare services and social protection.

The convention consists of the sixteen articles containing general provisions as well as the Code. The Code consists of five Titles in which specific provisions are grouped by standard (or in Title 5: mode of enforcement):

- Title 1 : Minimum requirements for seafarers to work on a ship
- Title 2 : Conditions of employment
- Title 3 : Accommodation, recreational facilities, food and catering
- Title 4 : Health protection, medical care, welfare and social security protection
- Title 5 : Compliance and enforcement

For Each Title, there are general Regulations, which are further specified in mandatory Standards (list A) as well as Guidelines (List B). Guidelines generally form a form of implementation of a Regulation according to the requirements, but States are free to have different implementation measures. Regulations and Standards should in principle be implemented fully, but a country can implement a "substantially equivalent" regulation, which it should declare upon ratification.

2.1.1 Seafarer Requirements

Seafarers are required to hold specialist maritime certification to work at sea. The minimum requirements set out in this section of the code are divided in 4 parts and are summarized below:

- Minimum age requirements: the minimum age is 16 years (18 for night work and work in hazardous areas).
- Medical fitness: workers should be medically fit for the duties they are performing. Countries should issue medical certificates as defined in the STCW (or use a similar standard).
- Training: Seafarers should be trained for their duties as well as have had a personal safety training.
- Recruitment/placement services located in member states or for ships flying the flag of member states should have (among others) proper placement procedures, registration, complaint procedures and compensation if the recruitment fails

2.1.2 Employment Conditions

The Title on employment conditions lists conditions of the contract and payments, as well as the working conditions on ships.

- Contracts: the contract should be clear, legally enforceable and incorporate collective bargaining agreements (if existent).
- Payments: Wages should be paid at least every month, and should be transferable regularly to family if so desired.
- Rest hours: rest hours should be implemented in national legislation. The maximum hours of work in that legislation should not exceed 14 hours in any 24-hour period and 72 hours in any seven-day period, or: at least ten hours of rest in any 24-hour period and 77 hours (rest) in any seven-day period. Furthermore, the daily hours of rest may not be divided into more than two periods and, at least six hours of rest should be given consecutively in one of those two periods.
- Leave: Seafarers have a right to annual leave as well as shore leave.
- Repatriation: Returning to their country of residence should be free.
- Loss: If a ship is lost or foundered, the seafarers have a right to an unemployment payments.
- Manning: Every ship should have a sufficient manning level.
- Development and opportunities: Every seafarer has a right to be promoted during his career except in cases where there is a violation of a statute or code of conduct, which inevitably hinders such promotion. Also, skill development and employment opportunities should be made available for each and every seafarer.

2.1.3 Accommodation, Recreational Facilities, Food and Catering

The title specifies rules detailed rules for accommodation and recreational facilities, as well as food and catering.

- Accommodation: Accommodation for living and/or working should be "promoting the seafarers' health and well-being". Detailed provisions (in rules and guidelines) give minimum requirements for various types of rooms (mess rooms, recreational rooms, dorms etc.).
- Food and Catering: Both food quality and quantity, including water should be regulated in the flag state. Furthermore, cooks should have proper training.

2.1.4 Health Protection, Medical Care, Welfare and Social Security Protection

Title 4 consists of 5 regulations about Health, Liability, Medical care, Welfare and Social security.

- Medical care on board ship and ashore: Seafarers should be covered for and have access to medical care while on board; in principle at no cost and of a quality comparable to the standards of health care on shore. Countries through which territory a ship is passing should guarantee treatment on shore in serious cases.
- Shipowners' liability: Seafarers should be protected from the financial effects of "sickness, injury or death occurring in connection with their employment". This includes at least 16 weeks of payment of wages after start of sickness.
- Health and safety protection and accident prevention: A safe and hygienic environment should be provided to seafarers both during working and resting hours and measures should be taken to take reasonable safety measures.
- Access to shore-based welfare facilities: Port states should provide "welfare, cultural, recreational and information facilities and services" and to provide easy access to these services. The access to these facilities should be open to all seafarers irrespective of race, sex, religion or political opinion.
- Social security: Social security coverage should be available to seafarers (and in case it is customary in the flag state: their relatives).

2.1.5 Compliance and Enforcement

Title 5 sets standards to ensure compliance with the convention. The title distinguishes requirements for flag state and port state control.

- Flag states: Flag states (the state under which flag the ship operates) are responsible for ensuring implementation of the rules on the ships that fly its flag. Detailed inspections result in the issue of a "Certificate of Maritime Compliance", which should always be present (and valid) on a ship. Ships are required to have decent complaints procedures in place for its crew and should institute investigations in case of casualties.
- Port States: The inspection in ports depends on whether a Certificate of Maritime Compliance is present (and thus a flag is flown of a country which has ratified the convention). If the Certificate is present, compliance is to be assumed in principle, and further investigations only take place if the certificate is not in order or there are indications of non-compliance. For ships that don't have the certificate, inspections are much more detailed and should ensure - according to a "no more favorable treatment principle"[6] that the ship has complied with the provisions of the convention. The convention is thus -indirectly- also valid for ships of non-member countries if they plan to call to ports of a member state.
- Labour agencies: Agencies supplying on maritime workers to ships should also be inspected to ensure that they apply the convention (among others the regulations regarding to social security).

2.2 Virtual Reality

Applications of Virtual Reality (VR) have and continue to increase over the last couple of years. This is partly due to its usefulness in many fields and as a result of the attention given to it by the media. This trend is expected to continue in the future with the advancement of technology in areas like computer graphics, computer vision, controls, image processing and other technology-affiliated components. This paper aims to dissect the nature, the role, the component, the application and applicability of the virtual reality system, as well as, explore briefly the characteristics and use of VR system hardware and software (Bamodu et al., 2013).

2.2.1 Definition of Virtual Reality Technology

There are some people to whom VR is a specific collection of technologies; that is, headset, glove and walker (Haag et al., 1998). VR is defined as a highly interactive, computer-based multimedia environment in which the user becomes the participant in a computer-generated world (Kim et al., 2000; Onyesolu, 2009a; Onyesolu & Akpado, 2009). It is the simulation of a real or imagined environment that can be experienced visually in the three dimensions of width, height, and depth and that may additionally provide an interactive experience visually in full real-time motion with sound and possibly with tactile and other forms of feedback. VR is a way for humans to visualize, manipulate and interact with computers and extremely complex data (Isdale, 1998). It is an artificial environment created with computer hardware and software and presented to the user in such a way that it appears and feels like a real environment (Baieier, 1993). VR is a computer-synthesized, three-dimensional environment in which a plurality of human participants, appropriately interfaced, may engage and manipulate simulated physical elements in the environment and, in some forms, may engage and interact with representations of other humans, past, present or fictional, or with invented creatures. It is a computer-based technology for simulating visual auditory and other sensory aspects of complex environments (Onyesolu, 2009b). VR incorporates 3D technologies that give a reallife illusion. VR creates a simulation of real-life situation (Haag et al., 1998).

Therefore, VR refers to an immersive, interactive, multi-sensory, viewer-centered, 3D computer-generated environment and the combination of technologies required to build such an environment (Aukstakalnis & Blatner, 1992; Cruz-Niera, 1993). By immersing viewers in a computer-generated stereoscopic environment, VR technology breaks down barriers between humans and computers. VR technology simulates natural stereoscopic viewing processes by using computer technology to create right-eye and left-eye images of a given 3D object or scene. The viewer's brain integrates the information from these two perspectives to create the perception of 3D space. Thus, VR technology creates the illusion that on-screen objects have depth and presence beyond the flat image projected onto the screen. With VR technology, viewers can perceive distance and spatial relationships between different object components more realistically and accurately than with conventional visualization tools (such as traditional CAD tools).

2.2.2 Classification

VR systems can be classified into 3 major categories. These are, non-immersive, immersive and semi-immersive, based on one of the important features of VR, which is immersion and the type of interfaces or components utilized in the system.

2.2.2.1 Non-Immersive

Non-Immersive VR system, also called Desktop VR system, Fish tank or Window on World system is the least immersive and least expensive of the VR systems, as it requires the least sophisticated components. It allows users to interact with a 3D environment through a stereo display monitor and glasses, other common components include space ball, keyboard and data gloves. Its application areas include modeling and CAD systems

2.2.2.2 Immersive

Immersive VR system on the other hand is the most expensive and gives the highest level of immersion; its components include HMD, tracking devices, data gloves and others, which encompass the user with computer generated 3D animation that give the user the feeling of being part of the virtual environment. One of its applications is in virtual walk-through of buildings (Blackedge et. Al, 2010).

2.2.2.3 Semi-Immersive

Semi-Immersive VR system, also called hybrid systems (Dani et. al. 1998), or augmented reality system, provides high level of immersion, while keeping the simplicity of the desktop VR or utilizing some physical model. Example of such system includes the CAVE (Cave Automatic Virtual Environment) and an application is the driving simulator (Blackedge et. Al, 2010).

2.2.2.4 Distributed-VR

Distributed-VR also called Networked-VR is a new category of VR system, which exists as a result of rapid development of internet. Its goal is to remove the problem of distance, allowing people from many different locations to participate and interact in the same virtual world through the help of the internet and other networks. A traditional application of this is the SIMNET which is a real time distributed simulation developed by the US military and used for combat trainings.

2.2.3 Components

A VR system is made up of 2 major subsystems, the hardware and software. The hardware can be further divided into computer or VR engine and I/O devices, while the software can be divided into application software and database as illustrated below.

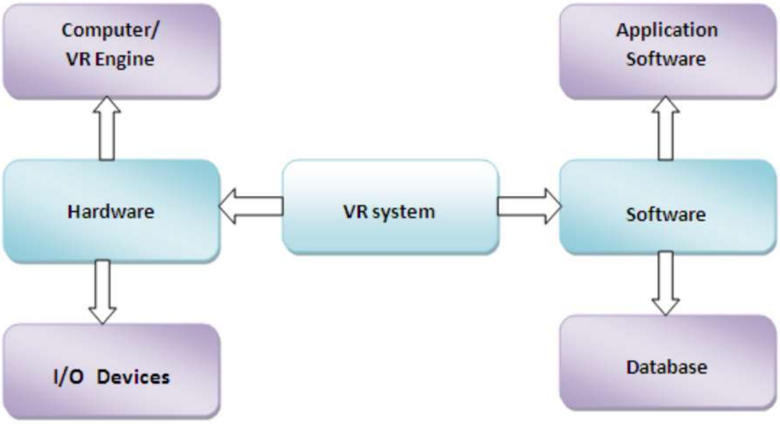

Figure 2. 1 Components of Virtual Reality System
(Source: Bamodu, 2013.)

2.2.3.1 Hardware

The major components of the hardware are the VR engine or computer system, input devices and output devices shown in figure below.

Figure 2.2 Virtual Reality System Hardware
(Source: Bamodu, 2013.)

The hardware components are divided into five sub-components: computer workstation, sensory displays, process acceleration cards, tracking system and input devices.

2.2.3.1.1 Computer Workstation

A computer workstation is a high-end microcomputer designed for technical or scientific applications. Intended primarily to be used by one person at a time, workstations are commonly connected to a local area network and run multi-user operating systems. The term workstation has also been used to refer to a mainframe computer terminal or a personal computer (PC) connected to a network.

2.2.3.1.2 Sensor Displays

Sensory displays are used to display the simulated virtual worlds to the user. The most common sensory displays are the computer visual display unit, the head-mounted display (HMD) for 3D visual and headphones for 3D audio.

2.2.3.1.3 Head Mounted Displays

Head mounted displays place a screen in front of each of the viewer's eyes at all times. The view, the segment of the virtual environment generated and displayed, is controlled by orientation sensors mounted on the “helmet”. Head movement is recognized by the computer, and a new perspective of the scene is generated. In most cases, a set of optical lens and mirrors are used to enlarge the view to fill the field of view and to direct the scene to the eyes (Lane, 1993).

2.2.3.1.4 Binocular Omni-Orientation Monitor

The BOOM is mounted on a jointed mechanical arm with tracking sensors located at the joints. A counterbalance is used to stabilize the monitor, so that when the user releases the monitor, it remains in place. To view the virtual environment, the user must take hold of the monitor and put her face up to it. The computer will generate an appropriate scene based on the position and orientation of the joints on the mechanical arm (Aukstakalnis & Blatner 1992). Some of the problems associated with HMDs can be solved by using a BOOM display. The user does not have to wear a BOOM display as in the case of an HMD. This means that crossing the boundary between a virtual world and the real world is simply a matter of moving your eyes away from the BOOM.

2.2.3.1.5 Visual Display Unit (VDU) or Monitor

There are two types of computer visual display unit. The CRT monitors and the LCD monitors. The distinguishing characteristics of the two types are beyond the scope of this piece.

2.2.3.1.6 Process Acceleration Cards

These cards help to update the display with new sensory information. Examples are 3D graphic cards and 3D sound cards.

2.2.3.1.7 Tracking System

This system tracks the position and orientation of a user in the virtual environment. This system is divided into: mechanical, electromagnetic, ultrasonic and infrared trackers.

2.2.3.1.8 Input Devices

They are used to interact with the virtual environment and objects within the virtual environment. Examples are joystick (wand), instrumented glove, keyboard, voice recognition etc.

2.2.3.2 Software

Virtual reality system software is a colletion of tools and software for designing, developing and maintaining virtual environments and the database where the information is stored. The tools can be classified into modeling tools and development tools.

2.2.3.2.1 Modeling Tools

There are many modeling tools available for VR designing, the most common ones are , 3ds Max, Maya and Creator. Engineering specific applications might use software like CATIA, Pro/E, Solidworks, UG, etc.

2.2.3.2.1.1 Blender

Blender is a free and open-source 3D computer graphics software toolset used for creating animated films, visual effects, art, 3D printed models, motion graphics, interactive 3D applications, and computer games. Blender's features include 3D modeling, UV unwrapping, texturing, raster graphics editing, rigging and skinning, fluid and smoke simulation, particle simulation, soft body simulation, sculpting, animating, match moving, rendering, motion graphics, video editing, and compositing.

In 2019, the integrated game engine for making and prototyping games was removed in the release of 2.80, with a recommendation to use more powerful open source game engines "like Godot."

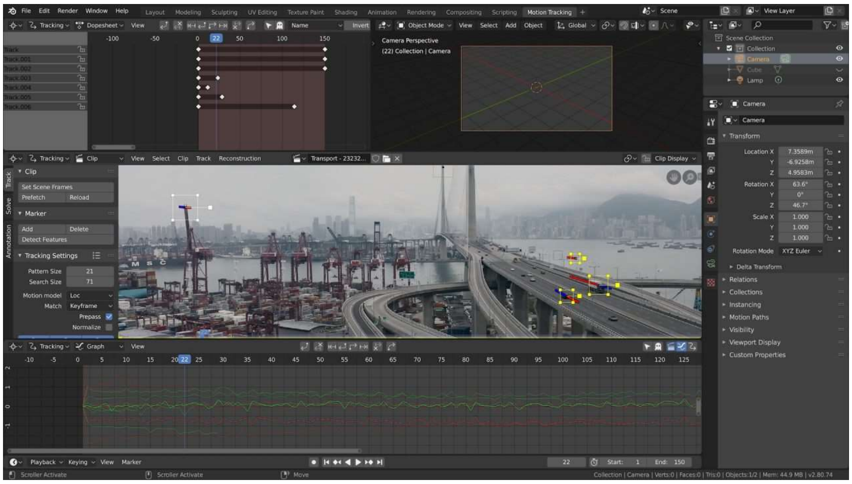

Figure 2.3 Blender 3D Modeling Software
(Source: blender.com)

2.2.3.2.2 Development Tools

VR is a complex and integrative technology that borrows from many other technologies, such as real time 3D computer graphics, tracking technology, sound processing, and haptic technology, among others, therefore software development flexibility and real time interaction is needed. Starting the development of a VR system from the basic codes in C/C++, Java, OpenGL, etc, requires a large amount of work and such system reliability is usually low, therefore VR development tools are used.

Careful consideration is needed in choosing VR development tools due to the difference in flexibility provided by different software packages as related to model input available, interface compatibility, file format, animation ease, collision detection, supported I/O devices and support community available to the users.

VR development tools used in VR content creation include, virtual world authoring tools, VR toolkits/software development kits (SDK) and application program interfaces (APIs). But it is not uncommon to find that some APIs are also toolkits, like OpenGL optimizer and Java 3D API (Dani et. al. 1998).

2.2.3.2.2.1 Unity 3D

Unity is a cross-platform game engine developed by Unity Technologies, first announced and released in June 2005 at Apple Inc.'s Worldwide Developers Conference as an OS X-exclusive game engine. As of 2018, the engine has been extended to support 27 platforms. The engine can be used to create both three-dimensional and two-dimensional games as well as simulations for its many platforms. Unity gives users the ability to create simulation in both 2D and 3D, and the engine offers a primary scripting API in C#, for both the Unity editor in the form of plugins, and games themselves, as well as drag and drop functionality. Prior to C# being the primary programming language used for the engine, it previously supported Boo, which was removed in the Unity 5 release, and a version of JavaScript called UnityScript.

The engine has support for the following graphics APIs: Direct3D on Windows and Xbox One; OpenGL on Linux, macOS, and Windows; OpenGL ES on Android and iOS; WebGL on the web; and proprietary APIs on the video game consoles. Additionally, Unity supports the low-level APIs Metal on iOS and macOS and Vulkan on Android, Linux, and Windows, as well as Direct3D 12 on Windows and Xbox One.

Within in 2D, Unity allows importation of sprites and an advanced 2D world renderer. For 3D simulation, Unity allows specification of texture compression, mipmaps, and resolution settings for each platform that the game engine supports, and provides support for bump mapping, reflection mapping, parallax mapping, screen space ambient occlusion (SSAO), dynamic shadows using shadow maps, render-to-texture and full-screen post-processing effects.

Figure 2.4 Unity 3D, VR Development Software
(Source: forum.unity.com)

2.2.4 Working Principle

The idea behind VR is to deliver a sense of being there by giving at least the eye what it would have received if it were there and, more important to have the image change instantly as the point of view is changed (Smith & Lee, 2004). The perception of spatial reality is driven by various visual cues, like relative size, brightness and angular movement. One of the strongest is perspective, which is particularly powerful in its binocular form in that the right and left eyes see different images. Fusing these images into one 3D perception is the basis of stereovision.

The perception of depth provided by each eye seeing a slightly different image, eye parallax, is most effective for objects very near you. Objects farther away essentially cast the same image on each eye. The typical dress code for VR is a helmet with goggle-like displays, one for each eye. Each display delivers a slightly different perspective image of what you would see if you were there. As you move your head, the image rapidly updates so that you feel you are making these changes by moving your head (versus the computer actually following your movement, which it is). You feel you are the cause not the effect.

2.2.5 Applications and Advancements

VR has found vast applications in many fields due to its characteristics and the benefits it provide in solving complex real-world problems. Some of the application areas include: Architecture, Arts, Business, Design and Planning, Education and Training, Entertainment, Manufacturing, Medical and Scientific Visualization.

In manufacturing, VR is used to remove limitations in virtualization and interaction associated with traditional 3D CAD/CAM systems through virtual manufacturing. Virtual manufacturing is virtual product design, modeling, simulation, assembly, testing and analysis for error before physical prototypes are built to reduce development time and avoid wasteful costs (Bamodu et. al, 2012).

2.2.6 Advantages and Uses of VR in Maritime Sector

Researchers in the field have generally agreed that VR technology is exciting and can provide a unique and effective way to learn and that VR projects are highly motivating to learners. From research, several specific situations have emerged in which VR has strong benefits or advantages. For example, VR has great value in situations where exploration of environments or interactions with objects or people is impossible or inconvenient, or where an environment can only exist in computer-generated form. VR is also valuable when the experience of actually creating a simulated environment is important to learning. Creating their own virtual worlds has been shown to enable some students to master content and to project their understanding of what they have learned (Ausburn & Ausburn, 2004).

One of the beneficial uses of VR occurs when visualization, manipulation, and interaction with information are critical for its understanding; it is, in fact, its capacity for allowing learners to display and interact with information and environment that some believe is VR's greatest advantage. Finally, VR is a very valuable instructional and practice alternative when the real thing is hazardous to learners, instructors, equipment, or the environment. This advantage of the technology has been cited by developers and researchers from such diverse fields as firefighting, anti-terrorism training, nuclear decommissioning, crane driving and safety, aircraft inspection and maintenance, automotive spray painting and pedestrian safety for children (Ausburn & Ausburn, 2004).

2.2.6.1 Design Review

Some of the leading shipyards in Germany are now in the process of integrating Virtual Reality into their standard design procedures (Mesing et al. 2008; Nedeß et al. 2009). Supported by national German research projects, they focus on using VR as a tool for review where participants of various disciplines and/or stakeholders have a natural environment to inspect the current model and discuss several aspects of the design (ref. Figure 2.5).

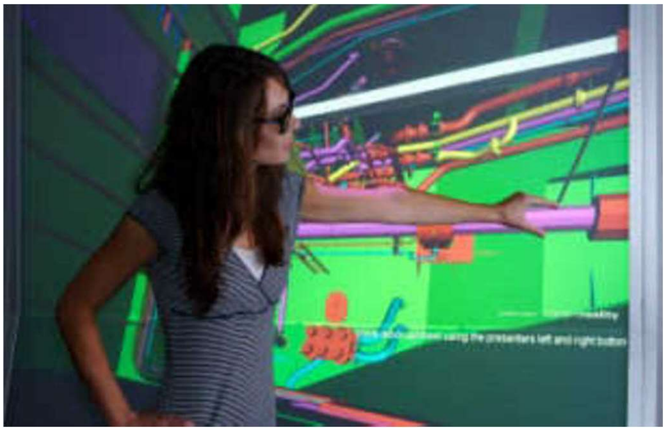

Figure 2.5 Virtual reality-based design review at Fraunhofer IGD's Maritime Graphics lab in Rostock
(Source: Lukas, 2010)

Research aspects in this context include the handling if the huge data sets in realtime, the efficient augmentation of the geometry data with meta data from external systems or functional behavior.

2.2.6.2 Game-Based Training for Maritime Security

The gaming industry does not only influence industrial applications with affordable high-end graphics boards but also with powerful software platforms. The game engines combine handling and rendering of 3D objects with an efficient way to describe interaction and behaviour. This specific mixture of gaming and "serious" simulation offers interesting perspectives for interactive training (Wolfe and Crookall, 1998).

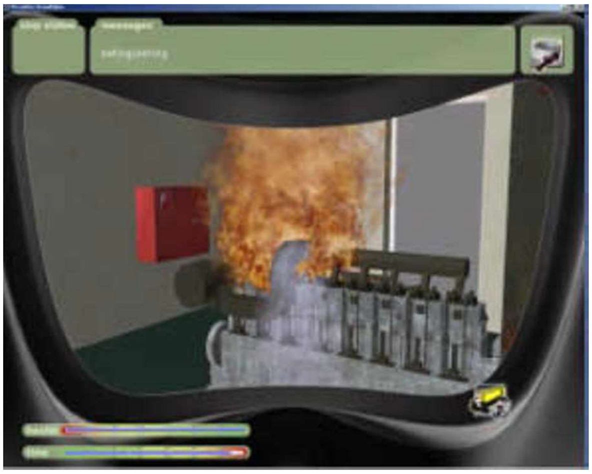

Figure 2.6 Virtual Fire-Fighting Application
(Source: Lukas, 2010)

A serious game approach introduces new media in the training of ship crews as illustrated in Figure 2.6. It shows a PC-based shipboard virtual fire-fighting application that is part of a blended learning course for basic fire-fighting (Deistung et al. 2008).

The authoring of such a training environment typically comprises a lot of manual work. Current research aims for a high degree of automation where the virtual world is directly derived from the CAD data.

2.2.6.3 Simulation-Based Training for Operators

Simulation based training is state of the art for pilots of aircrafts as well as nautical officers. It is even more important for a completely new kind of vessel such as a wing-in-ground craft which is quite difficult to handle and operates with high speed. Wing in ground crafts (WIG) are a good example for the type of vessels. Based on a MATLAB simulation and the mixed reality framework instantReality (Fellner et al. 2009), a scalable solution was implemented that mimics the behaviour of an 140 hm/h WIG craft (ref. Figure 2.7). One of the challenges here is to replace the complex equations of motion by approximations that are accurate enough but solvable in real-time.

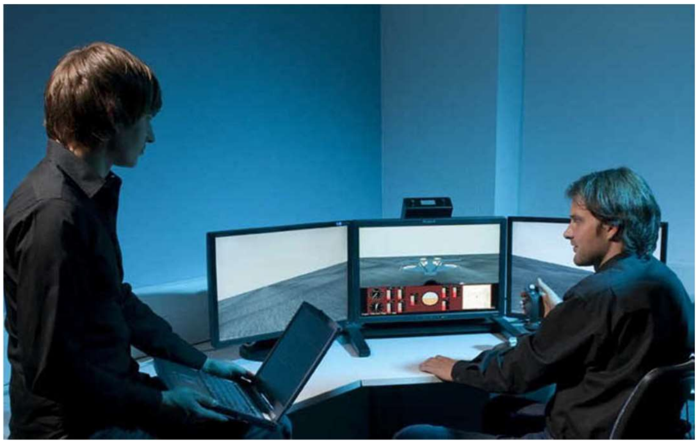

Figure 2.7 WIG simulator with tiled display
(Source: Lukas, 2010)

Such a Human-in-the-Loop approach (Smid and Cheok 1998) does not only serve for training purposes but also allows the optimization of the simulated vessel (Johnson and Fontaine 2001). Another challenge, where it is crucial to have well-trained personnel is for underwater vehicle operators (ref. Figure 2.8). Like in the case of

WIG crafts, the real-time graphics and simulators can offer an extremely efficient and cheap approach for practicing the handling of a complex technical object (Ridao et al. 2004).

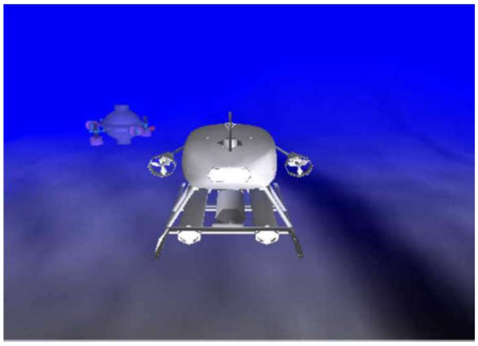

Figure 2.8 UV Simulator NEPTUNE
(Source: University of Girona, 2004)

Beside the training aspect, those simulators play an important role in AUV or ROV development. They support the engineers in reviewing the behavior (such as maneuverability) of the designed vehicle. Some of them even serve as a basis for hardware in the loop, where virtual objects can be mixed with real objects (Song et al.2001).

2.3 Expected Result

The result of this thesis will be in the form of a mobile application. The final application is expected to be used for both inspection and educational purpose, objected towards the maritime industry stakeholders, mainly surveyors, crews, trainees and students who are pursuing related study. This type of application had been developed by Rafiqi Zulfauzi in 2019, but the application mainly concerns on Life-Saving Appliances inspection training (Rafiqi, 2019), while in this final project, the focus of the application will rely more onto the accommodation, recreational facilities, food and catering, and other aspects that are in compliance with Maritime Labour Convention 2006.

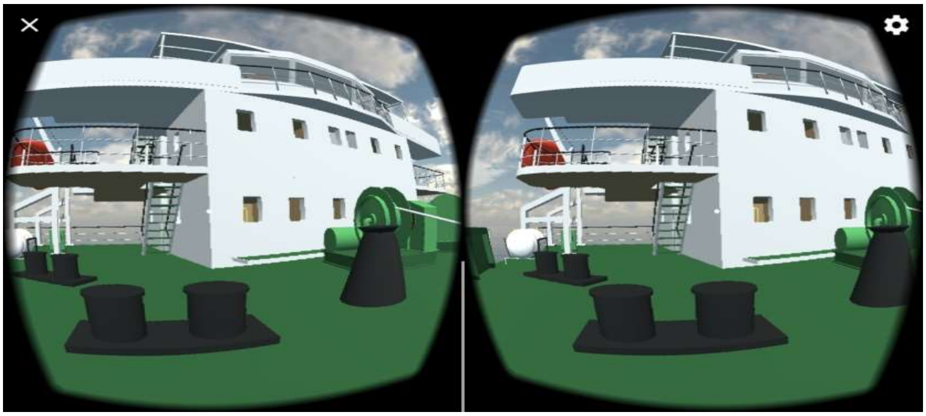

Figure 2.9 Virtual Reality-based Inspection Training Mobile Application
(Source: Rafiqi, 2019.)

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CHAPTER III
METHODOLOGY

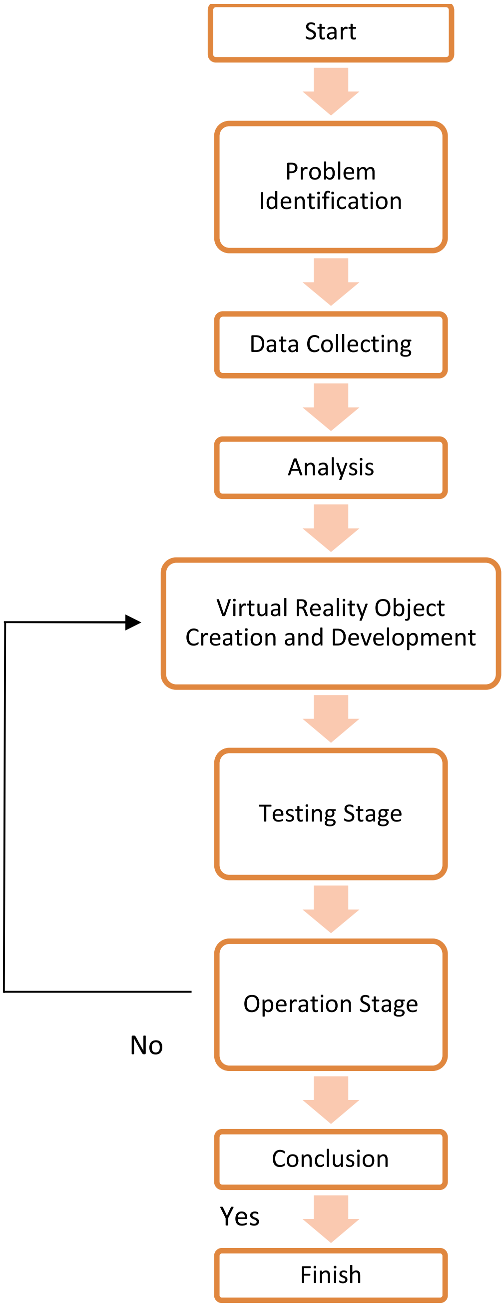

Figure 3.1 Methodology

3.1 Problem Identification

The first stage of the methodology used in this final project is identifying the problem, and then formulate the problem to be used as an object of research. The problem that will be raised in this thesis is how to apply Virtual Reality technology as an educational medium for studying about Maritime Labour Convention, 2006.

3.2 Literature Study

The purpose of a literature study is to summarize the basic theories and supporting information that will be discussed and then become the basis of this research. This literature review is carried out by summarizing reference sources related to this research. This literature review is obtained from books, journals, papers, and others.

3.3 Data Collecting

This stage is carried out in parallel with the literature review. This stage is the process of collecting data and technical information related to the problem object that serves as a basis for research. The data that will be collected for this final project are ship's compliances that are related to Maritime Labour Convention inspection checklists, such as seafarer documents, accommodation room, recreational facilities, food and catering, health protection, medical care, welfare, social security protection, and etc.

3.4 Analysis

In this stage begins with make the detailed scenario in virtual reality program by defining every object that needs to be built in VR simulation. The output of this phase now needs to be analyzed to get the foundation to build the whole application upon. This must be conducted especially carefully, because minor faults in this phase will steer the direction of progress off course.

3.5 Virtual Reality Object Creation and Development

This stage consists of creating every aspect for the virtual environment, the small bricks that build the whole virtual world. The requirements for some assets can be clear from earlier phases of the analyses or even from the scenario draft. All the object should be tested, and documentation should be made accordingly. There are many kinds of objects, scripts, texts, graphics, animations, sounds and hardware that are going to be developed in this phase.

3.6 Testing Stage

Testing stage will be done thoroughly, and it will cover every aspect of the virtual reality project. The tests should focus not only errors and unhandled exceptions in the code, but also for the overall feel of the virtual environment. The purpose of this phase is to confirm that it is progressing in accordance with requirements.

3.7 Operation Stage

In this stage, the virtual reality program that has been made in android platform-based will be fully tested by using cardboard/virtual reality glasses and smartphone. if it passes in this testing phase it will proceed to the next stage and if it doesn't pass it will be back to creation VR object phase.

3.8 Conclusion

The final step of research for this final project is to draw conclusions from the entire process that has been carried out, along with providing answers to some existing problems. Then proceed with giving recommendation based on the results of this study, which will then be used as a basis for further research, both directly related to this thesis and data and methodology that will be used as reference materials.

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CHAPTER IV
DATA ANALYSIS

4.1 Data Collection

In the making of this Virtual Reality application, the main and supporting data are collected from these following sources:

- General Information of a ship
  General information is mainly used to know the dimensions of the ship which will help the development of 3D modelling, in which the dimension of the virtual ship is on a comparable scale. Also, the other important information in the case of MLC, 2006 compliance include ship's flag and its number of crew.
- General Arrangement
  General Arrangement will be the main source of the virtual ship room layouting. It is very important since this application mainly deals with crew accommodation.
- ILO MLC, 2006 and ILO MLC Pocket Checklist by Lloyd Register
  The function of the two books is to help the author in deciding which equipment or part of the ship that should be left on or off in the application. Also, they will be the main sources of the written content in the virtual reality application.
- Visual data
  Photos and videos on the actual condition based on a survey that has been conducted. However due to COVID-19 pandemic, the author was not able to conduct a full survey to take visual data of the ship, therefore only available and documented visual data are used in the development of this VR application.

4.1.1 Research Object

A real ship is needed to be used as an object of research which will later be analyzed and converted into a 3D model. Due to its availability the research object of this thesis is MV. Meratus Benoa which is a Container Carrier owned by a shipping company in Surabaya named PT. Meratus Line.

Figure 4.1 MV. Meratus Benoa
(Source: Reyhan Ramadhan, 2014)

4.1.2 Ship Information

The data of ship general information below will be used to determine the proportional scale of ship for the modelling phase, as well as to understand the regulations applied in the ship related to MLC, 2006 compliance which is mostly based on the ship's flag, gross tonnage, and number of crew.

Table 4.1 Ship General Info

General Info	
Name	MV. Meratus Benoa
IMO	9509231
MMSI	525025061
Call Sign	PNPC
Flag	Indonesia
Vessel Type	Cargo
Gross Tonnage	3668 T
Deadweight	5107 t
Length Overall x Breadth Extreme	106,68m x 20,6m
Draught	4,215 m
Crew	15
Built	Indonesia
Home Port	Surabaya

4.1.3 List of Equipment

In order to make a virtual reality environment, all the ships compartment especially ones which relate to the MLC, 2006 compliance need to be listed down before being converted into 3D models. These equipment's actual condition was not validated due to COVID-19 pandemic, hence the list is obtained based on General Arrangement and a few real photos taken before the pandemic.

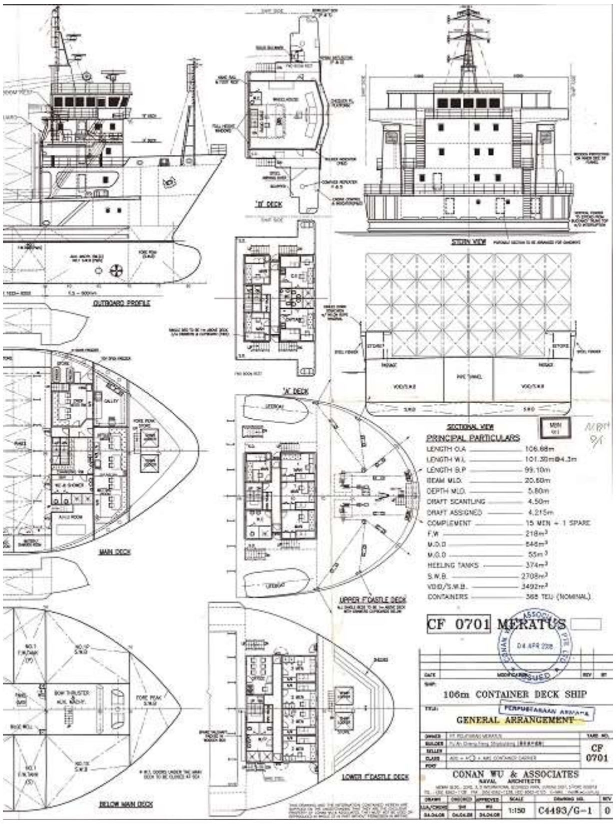


Figure 4.2 General Arrangement of MV. Meratus Benoa Accommodation Area
(Source: PT. Meratus Line Company Archive)

The table below summarizes the list of equipment in ship's accommodation deck that is relevant to the material of ship inspection according to MLC, 2006 compliance.

Table 4.2 List of Equipment

Equipment	Location		Quantity
Berth	Deck A	Captain Room	1
		Chief Officer Room	1
		Owner / Guest Room	1
		Officer Room 1	1
	Upper Forecasle	Officer Room 2	1
		Officer Room 3	1
		Officer Room 4	1
		Officer Room 5	1
Double Tier Berth	Lower Forecastle	Officer Room 6	1
		Officer Room 7	1
		Officer Room 8	1
		Officer Room 9	1
Locker	Deck A	Captain Room	1
		Chief Officer Room	1
		Owner / Guest Room	1
		Officer Room 1	1
	Upper Forecastle	Officer Room 2	1
		Officer Room 3	1
		Officer Room 4	1
		Officer Room 5	1
Double Locker	Lower Forecastle	Officer Room 6	1
		Officer Room 7	1
		Officer Room 8	1
		Officer Room 9	1
Mess Locker	Main Deck	Laundry Room	15
Desk	Deck A	Captain Room	1
		Chief Officer Room	1
		Owner / Guest Room	1
		Officer Room 1	1
	Upper Forecasle	Officer Room 2	1
		Officer Room 3	1
		Officer Room 4	1
		Officer Room 5	1
	Lower Forecastle	Officer Room 6	1
		Officer Room 7	1
		Officer Room 8	1
		Officer Room 9	1
Long Office Desk		Office Room	1
Chair	Deck B	Wheelhouse	2
	Deck A	Captain Room	1
		Chief Officer Room	1
		Owner / Guest Room	1
		Officer Room 1	1
	Upper Forecastle	Officer Room 2	1

		Officer Room 3	1
		Officer Room 4	1
		Officer Room 5	1
	Lower Forecastle	Officer Room 6	1
		Officer Room 7	1
		Officer Room 8	1
		Officer Room 9	1
		Office Room	2
	Main Deck	Officer Mess Room	8
		Mess Room	4
Long Couch	Main Deck	Officer Mess Room	1
		Mess Room	1
Accommodational and Recreational Facilities (Television, Portable Water Heater, Radio, etc.)	Main Deck	Officer Mess Room Mess Room	1 set 1 set
Galley Set (Stove, Sink, Refrigerator, Portable Fire Extinguisher, Cupboard, etc.)	Main Deck	Galley	1 set
Refrigerator	Main Deck	Officer Mess Room Mess Room Galley Store Room	1 1 1 2
Washing Machine	Main Deck	Laundry Room	2
Inner Toilet	Deck A	Captain Room Chief Officer Room	1 1
Shower	Deck A	Sanitary Room	1
Toilet	Deck A	Sanitary Room	1
Sink	Deck A	Sanitary Room	1

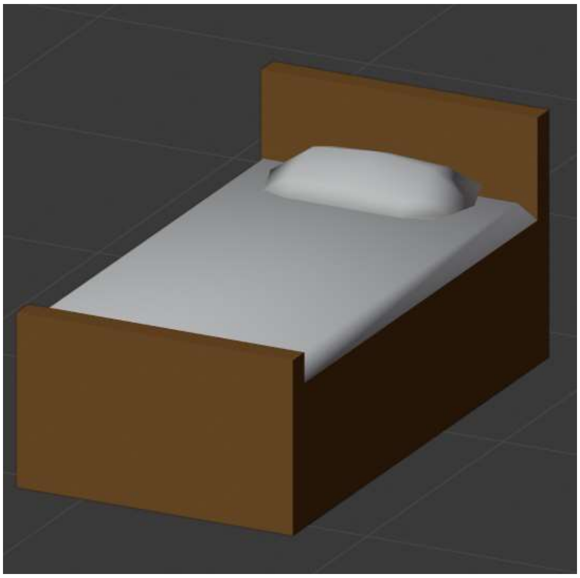
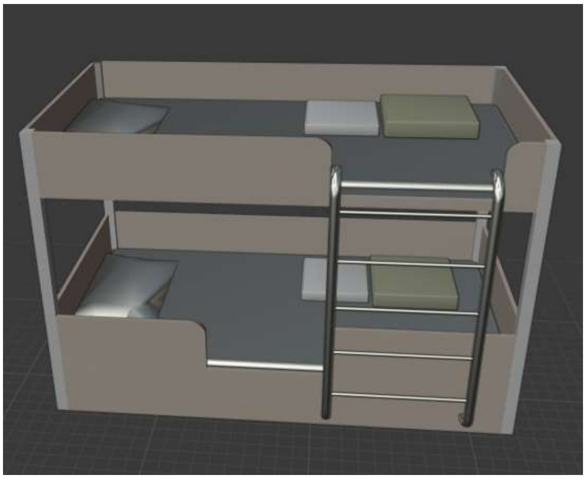
4.2 3D Modelling

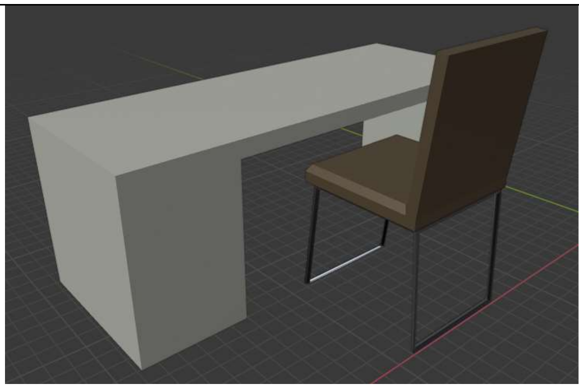
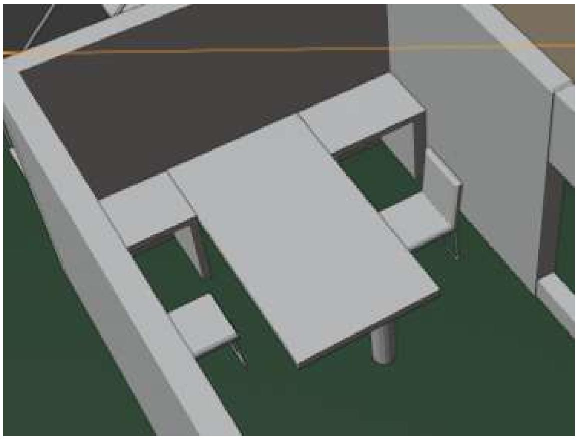
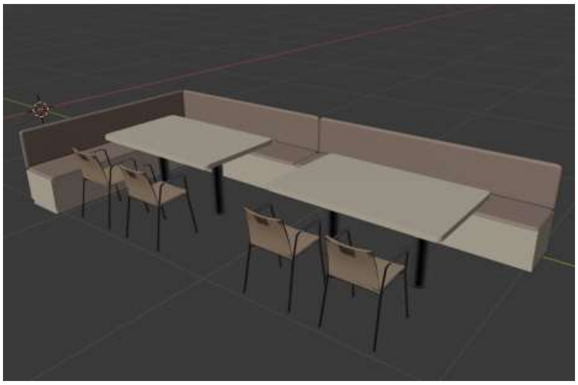
In this stage, every equipment that has been listed previously are being modelled into 3D objects. The process of modelling the equipment as well as other 3D assets (environment, etc.) are done using an open source software called Blender. The 3D assets for this VR application are mainly include: 3D Equipment, 3D Model of Crew, 3D Model of Ship Accommodation Area, as well as other supporting environment.

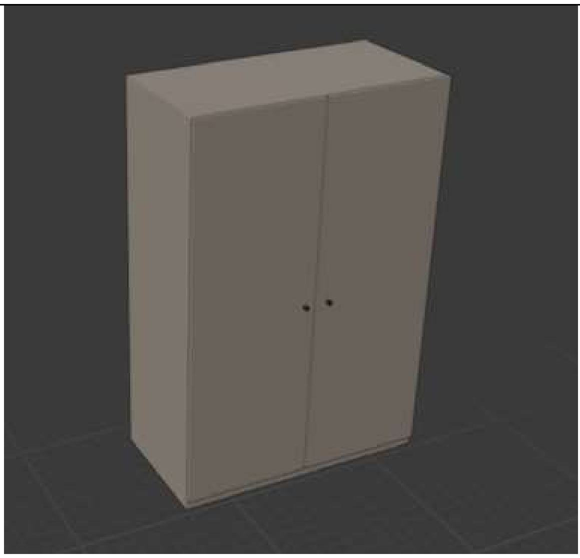
4.2.1 3D Model of Equipment

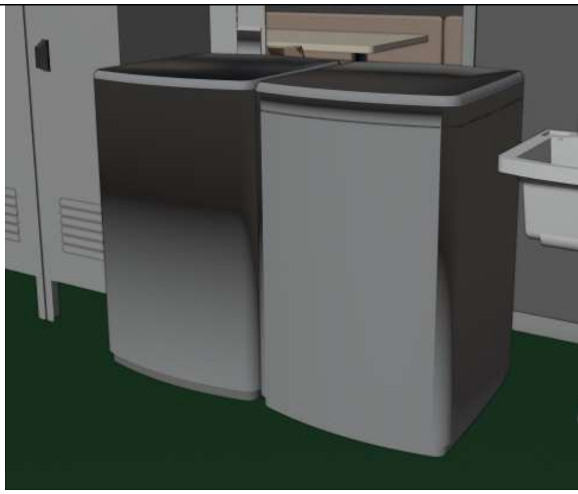
The table below lists down the 3D model of every equipment that will be used in the Virtual Reality application.

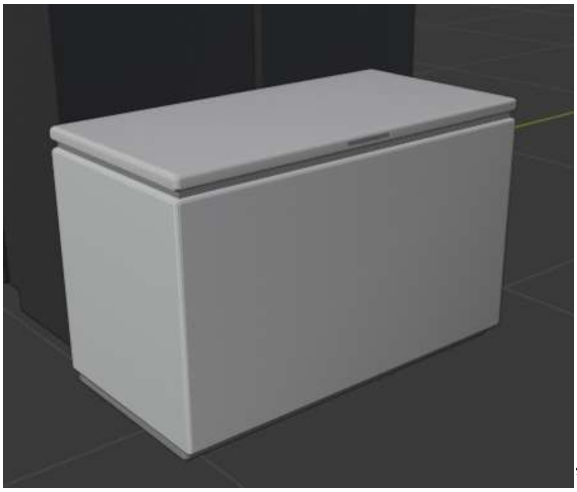
Table 4.3 3D Model of Equipment and Crew

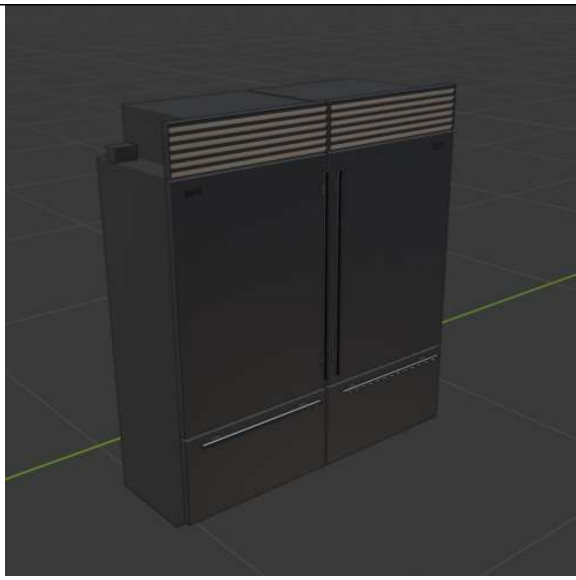
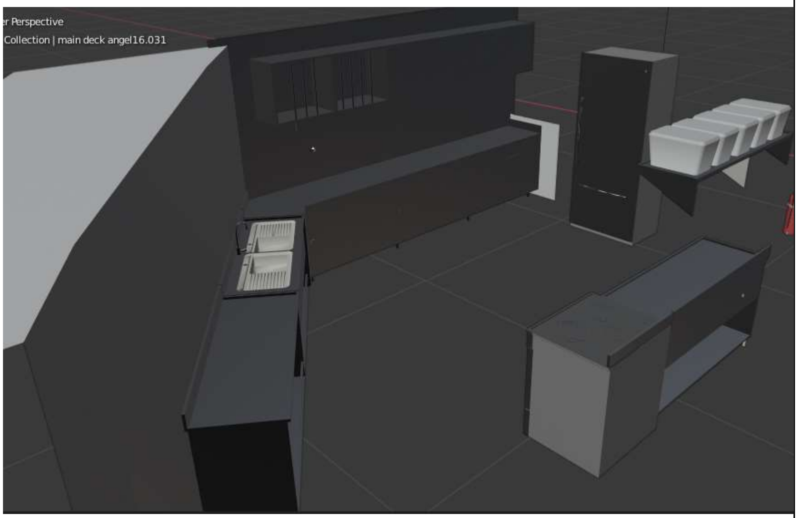
Equipment	3D Model
Berth	
Double Tier Berth	
Desk and Chair	

	
Office Desk and Chair	
Long Couch and Table (Mess Room)	
Locker	

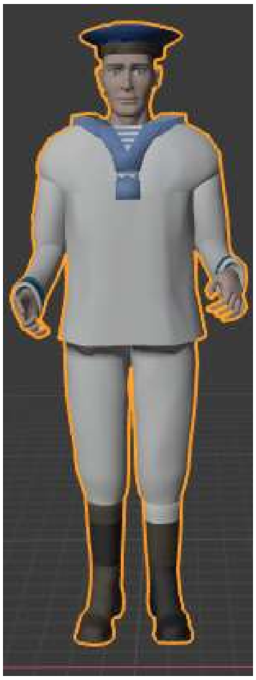
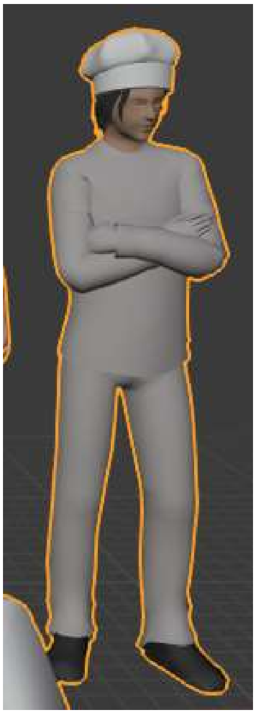
	
Mess Locker	

Washing Machine	
Inner Toilet	
Sanitary Room (a) Sink (b) Shower (c) Toilet	

	
Store Room Refrigerator	,

	
Galley Set (a) Refrigerator (b) Stove (c) Storage (d) Container Box (e) Sink	
Crew	**3D Model**
Captain	

	
Chief Engineer	
Officer	

	
Cook	
Steward	

4.2.2 3D Model of Accommodation Deck

Not only the equipment and model of crew that are converted to virtual objects, all the decks in the accommodation area including: Wheelhouse, Deck A, Upper and Lower Forecastle Deck, and Main Deck are also converted into 3D, and they will later be used as the main virtual environment of the game. Room arrangement and dimension are made as accurate as possible because those aspects have to comply the MLC, 2006 requirement.

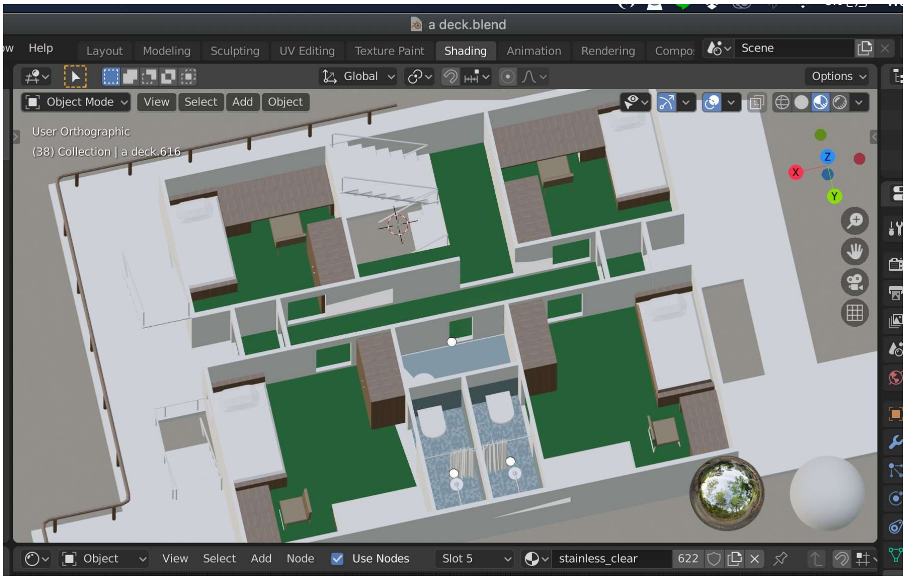


Figure 4.3a A Deck Accommodation Area
(Source: Author)

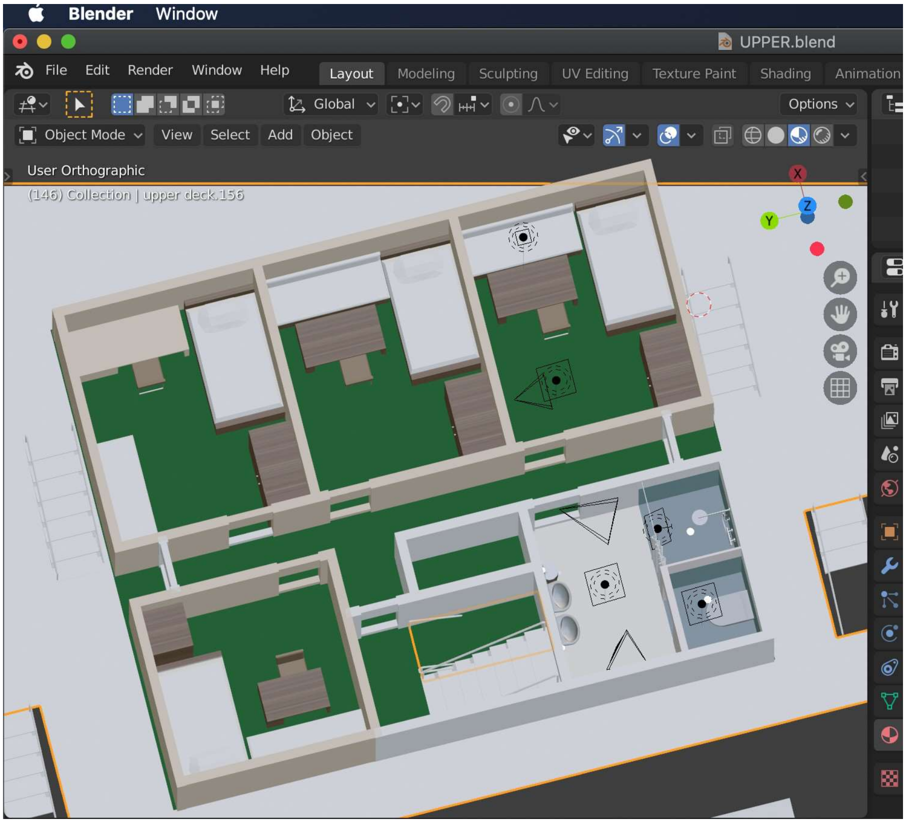


Figure 4.3b Upper Forecastle Deck Accommodation Area
(Source: Author)

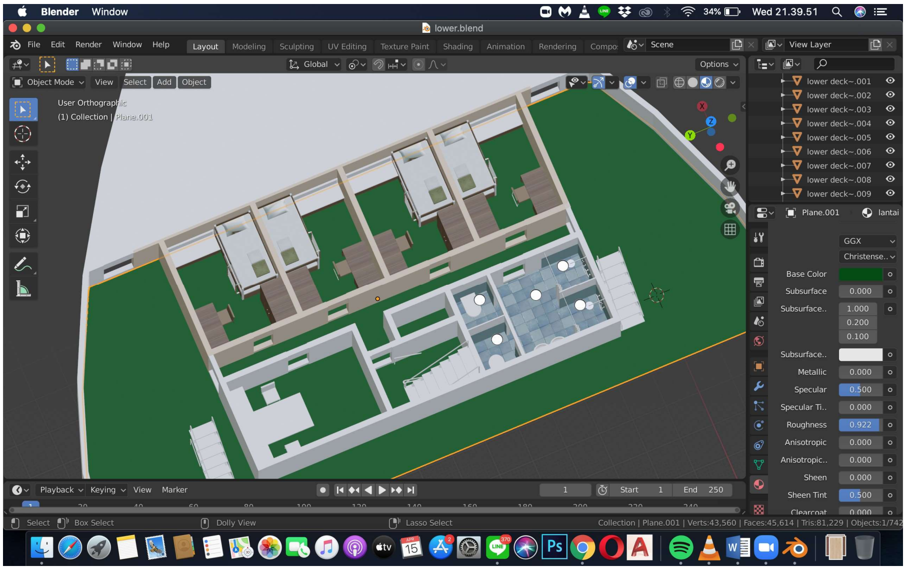


Figure 4.3c Lower Forecastle Deck Accommodation Area
(Source: Author)

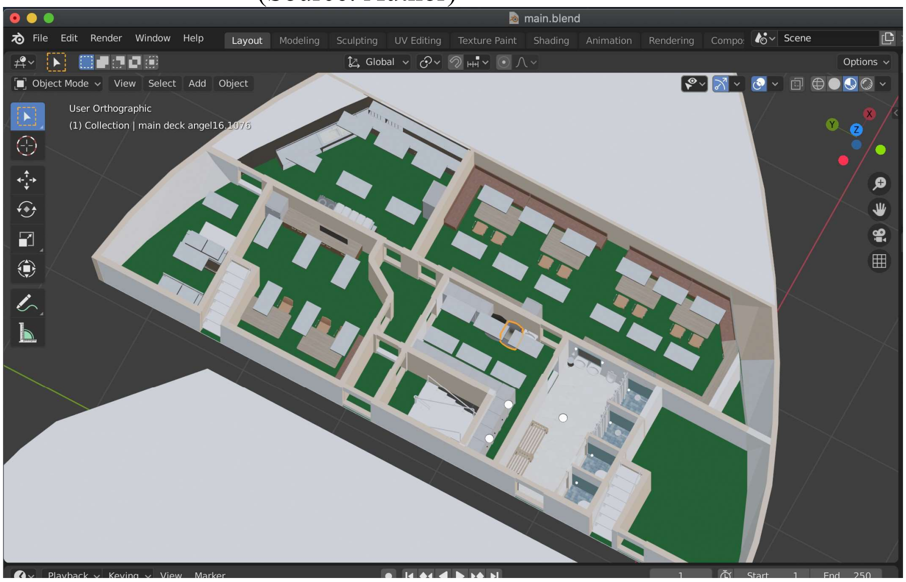


Figure 4.3d Main Deck
(Source: Author)

4.3 Virtual Reality Application

This is the phase where all the 3D and other visual assets are going to be used and assembled together in one virtual environment which eventually become a one world of Virtual Reality. The making of this Virtual Reality application is done using a open source real-time development platform called Unity3D. The major elements of the

Virtual Reality application consist of: User Interface; Game Mode; and Inspection Checklist Tab.

4.3.1 User Interface

The table below lists down the 3D model of every equipment that will be used in the Virtual Reality application.

Figure 4.4 Start Menu Introduction
(Source: Author)

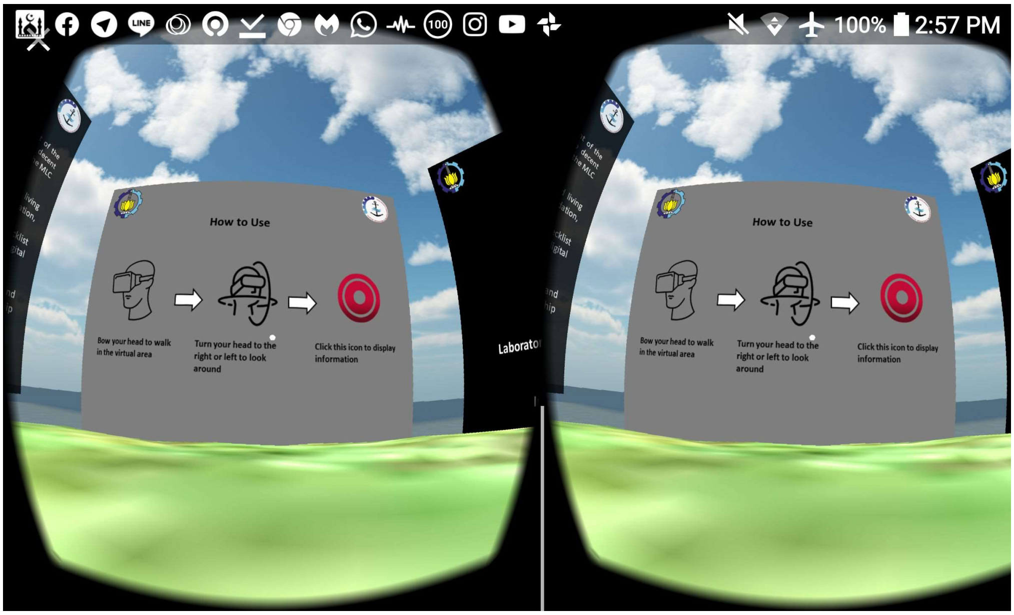


Figure 4.5 Guideline
(Source: Author)

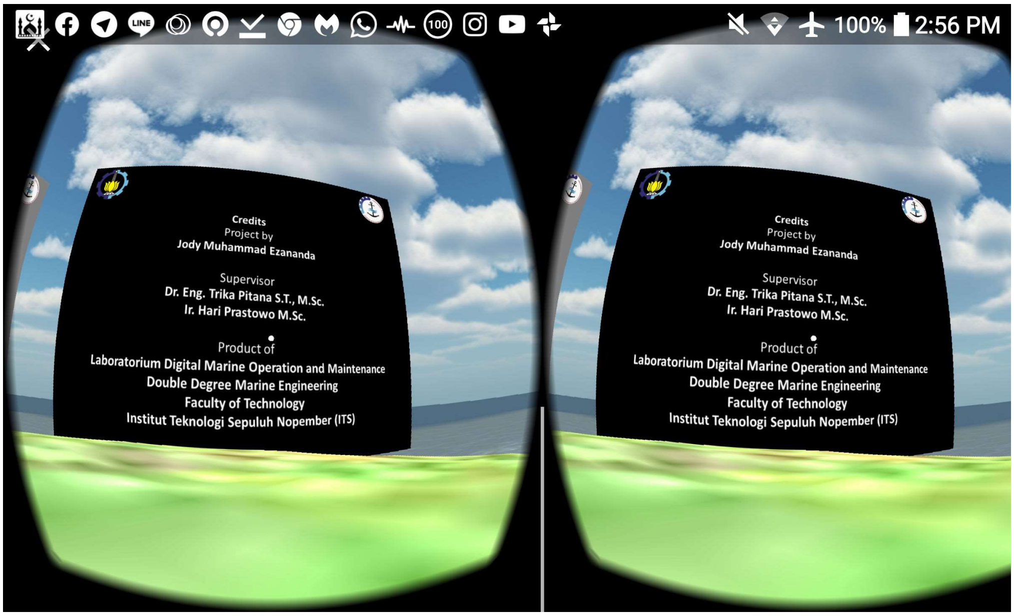


Figure 4.6 Credits
(Source: Author)

4.3.2 Game Mode

The table below lists down the 3D model of every equipment that will be used in the Virtual Reality application.

Table 4.4 Item Description in Game Mode

Equipment	Description
Berth	• Individual Berth must be provided in any circumstances, with following requirements: • Minimum Dimension = 198 cm x 80 cm • An electric reading lamp should be installed at the head of each berth. • In the case of berths placed along the ship's side, there should be only a single tier where a sidelight is situated above a berth.

Double-Tier Berth	• In ships w/ < 3,000 GT, sleeping rooms may be occupied by a maximum of two seafarers
	
	• Berths should not be arranged in tiers of more than two, with:
	
	  • The lower berth should be not less than 30 cm above the floor;
	
	  • The upper berth should be placed approximately midway between the bottom of the lower berth and the lower side of the deckhead beams.

Locker	• Furniture shall include a clothes locker of ample space (minimum 475 litres) and a drawer or equivalent space of not less than 56 litres • If the drawer is incorporated in the clothes locker then the combined minimum volume of the clothes locker shall be 500 litres; it shall be fitted with a shelf and be able to be locked by the occupant so as to ensure privacy.
Desk & Chair (Sleeping Room)	• Shall be provided with a table or desk, which may be of the fixed, drop-leaf or slide-out type, and with comfortable seating accommodation as necessary.

	• The tops of tables and seats should be of damp-resistant material.
Office Room	• All ships shall be provided with separate offices or a common ship's office for use by deck and engine departments
Mess Room	• Mess rooms shall be located apart from the sleeping rooms and as close as practicable to the galley • Mess rooms shall be of adequate size and comfort and properly furnished and equipped (including ongoing facilities for refreshment) • Should be equipped with appropriate seats, fixed or movable, sufficient to accommodate the greatest number of seafarers likely to use them at any one time. • Floor area for each person seating not less than 1 m2
Mess Room Accommodation Facilities	• There should be available at all times when seafarers are on board: (a) a refrigerator, which should be conveniently situated and of sufficient capacity for the number of persons using the mess room or mess rooms; (b) facilities for hot beverages; and (c) cool water facilities.
Mess Room Recreational Facilities	• Furnishings for recreational facilities should as a minimum include a bookcase and facilities for reading, writing and, where practicable, also:

	• television viewing and the reception of radio broadcasts; • showing of films, the stock of which should be adequate for the duration of the voyage and, where necessary, changed at reasonable intervals; • electronic equipment such as a radio, television, video recorders, DVD/CD player, personal computer and software and cassette recorder/player.
Sanitary Room	• All seafarers shall have convenient access on the ship to sanitary facilities meeting minimum standards of health and hygiene and reasonable standards of comfort, with separate sanitary facilities being provided for men and for women; • In all ships a minimum of one toilet, one wash basin and one tub or shower or both for every six persons or less who do not have personal facilities shall be provided at a convenient location; • Hot and cold running fresh water shall be available in all wash places.
Inner Toilet	• If reasonable and practicable, sleeping rooms should be planned and equipped with a private bathroom, including a toilet, so as to provide reasonable comfort for the occupants and to facilitate tidiness.
Washing Machine	• The laundry facilities provided for seafarers' use should include: (a) washing machines (b) drying machines or adequately heated and ventilated drying rooms

	(c) irons and ironing boards or their equivalent.
Mess Locker	• Adequate lockers for mess utensils and proper facilities for washing utensils should be provided.
Galley	• Ships that fly its flag meet the following minimum standard: (a) food and drinking water supplies, having regard to the number of seafarers on board, their religious requirements and cultural practices as they pertain to food, and the duration and nature of the voyage, shall be suitable in respect of quantity, nutritional value, quality and variety; (b) the organization and equipment of the catering department shall be such as to permit the provision to the seafarers of adequate, varied and nutritious meals prepared and served in hygienic conditions; and (c) catering staff shall be properly trained or instructed for their positions. • All casings and bulkheads of galleys and other spaces in which heat is produced should be adequately insulated where there is a possibility of resulting heat effects in adjoining accommodation or passageways.

4.3.3 Inspection Checklist Tab

This inspection checklist tab will appear very early in the game, before getting into the Inspection Tour, this checklist will work as a helping document that accompany user to do the inspection tour. The list of items in the checklist has been curated from the official Maritime Labour Convention, 2006 book (ILO, 2006) and a shorter pocket version that had been analyzed by Lloyd Register entitled ILO MLC Pocket Checklist (LR, 2012).

The list of items in the checklist are compiled in the Table 4.5 below:

Table 4.5 Inspection Checklist Question

No.	Item	Yes	No
1.	General Arrangement plans of the vessel's accommodation are available and up to date		
2.	Records of the Master's inspections of the vessel's accommodation are maintained and available		
3.	Accommodation spaces are clean and in a good state of repair, and fixtures and fittings are in place and in good working order		
4.	Mess rooms are clean, hygienic and comfortable		
5.	Cabins have hot and cold running water		
6.	Bedding is clean and hygienic		
7.	Heating and ventilation, including air conditioning, where fitted, is adequate and well-maintained		
8.	Sanitary facilities are accessible, hygienic and working correctly		
9.	The laundry facilities are in good working order		
10.	Adequate natural and artificial light is available		
11.	Noise and vibration experienced within the accommodation are within limits established by the flag state		
12.	Recreational facilities are appropriate and in good working order, and may include TVs/DVDs and sports equipment, including exercise equipment and games		
13.	The galley is clean, hygienic and in a good state of repair		
14.	Spaces used for the storage of food are clean, hygienic and in a good state of repair		
15.	Temperatures of refrigerators and freezers are appropriate		
16.	Food is of good quality and quantity and caters for different religious beliefs among the crew		

17.	Food is provided free of charge on board the vessel		
18.	Drinking water is of good quality and the quantity available is appropriate		
19.	The cook is over 18 years of age and holds appropriate qualifications, in accordance with the flag state's laws and regulations		
20.	All other catering staff are adequately trained (a training programme, posters, etc., may be available)		

4.4 User Assessment

After its development, the VR application needs to undergo a thorough trial. The function of this trial is to find technical errors and bug (or deficiency) in the software. At the same time, the trial will also be done by users, to determine whether the application has met the criteria based on the purpose of its development. A supporting questionnaire will also be used to help the user assessing the software. This questionnaire and the application are uploaded online and can be accessed at www.bit.ly/VRMLC.

4.4.1 User Assessment Questionnaire

The user assessment questionnaire consists of 8 questions, in which the last two questions are intended only for Surveyor or other Marine Practitioner (such as designer, seafarer, port master, trainer, students, etc.). The scoring goes from Five (5) to One (1), where 5 indicates excellence and 1 indicates inferiority.

The questions are as follows:

1. Is the display in this VR application easy to understand?
2. When using VR glasses, is the application comfort to use?
3. Does the object displayed represent its actual condition on board?
4. Is learning with VR technology more interesting, helpful and easy learning?
5. Can learning and training using VR be delivered and be a complement to face-to-face learning?
6. Does the inspection training using VR adequately illustrate hands-on learning on board?
7. If you are inspection survey trainee / marine student / other marine practitioner, has the application delivered MLC, 2006 training inspection materials well?
8. If you are inspection survey trainee / marine student / other marine practitioner, is this application helpful for inspection training purposes?

In the questionnaire, user is also requested to mention their device type, in order to see if the software is compatible to the respected device.

4.4.2 User Assessment Questionnaire Response

The following table (Table 4.6) sums up of collecting data from each answer from ten respondents who have filled the questionnaire online or paper-based; it can be seen in

Table 4.6 User Assessment Questionnaire Response

No.	Question	Score					Total
		5	4	3	2	1	
1.	Is the display in this VR application easy to understand?	2	6	2	0	0	10
2.	When using VR glasses, is the application comfort to use?	1	6	3	0	0	10
3.	Does the object displayed represent its actual condition on board?	2	5	2	1	0	10
4.	Is learning with VR technology more interesting, helpful and easy learning?	6	3	1	0	0	10
5.	Can learning and training using VR be delivered and be a complement to face-to-face learning?	4	5	1	0	0	10
6.	Does the inspection training using VR adequately illustrate hands-on learning on board?	4	5	1	0	0	10
7.	If you are surveyor / other marine practitioner, has the application delivered MLC, 2006 training inspection materials well?	2	3	2	0	0	7
8.	If you are surveyor, is this application helpful for inspection training purposes?	3	3	1	0	0	7

List of Devices used by users:

1. OPPO F11
2. Xiaomi Mi 8 SE
3. Samsung A70
4. Sony Xperia
5. Android Emulator (Desktop)

4.4.3 User Response Analysis

The data collected from user assessment response can be analyzed to obtain a quantitative score for the VR application. The percentage value of each question response can be done using Likert scale formula as follows:

$$P = \frac{S}{Ideal\ Score} \times 100\%$$

The description of the formula for calculates score and percentage value of the questionnaire answers can be seen in Table 4.7:

Table 4.7 Calculation Formula

	Description
P	Percentage Value
S	The number of times the frequency is multiplied by the score in the answer
Ideal Score	Highest score multiply by the number of samples
Highest Score	5
Sample	Number of Respondents = 10
Ideal Score	5 x 10 = 50

Below is score and percentage calculation from each answer, as well as the analysis:

1. Is the display in this VR application easy to understand?

Table 4.8 Question 1 Response

Score	Respondent	Total Score
5	2	10
4	6	24
3	2	6
2	0	0
1	0	0
Total	10	40
Total Average Score		4,0

Converting the score into percentage:

$$P = \frac{40}{50} \times 100\% = 80\%$$

Therefore, it can be concluded that the VR application is easy to understand.

2. When using VR glasses, is the application comfort to use?

Table 4.9 Question 2 Response

Score	Respondent	Total Score
5	1	5
4	6	24
3	3	9
2	0	0
1	0	0
Total	10	38
Total Average Score		3,8

Converting the score into percentage:

$$P = \frac{38}{50} \times 100\% = 76\%$$

Therefore, it can be concluded that the VR application is comfortable to use.

3. Does the object displayed represent its actual condition on board?

Table 4.10 Question 3 Response

Score	Respondent	Total Score
5	2	10
4	5	20
3	2	6
2	1	2
1	0	0
Total	10	38
Total Average Score		3,8

Converting the score into percentage:

$$P = \frac{38}{50} \times 100\% = 76\%$$

Therefore, it can be concluded that the VR application represents the actual condition on board.

4. Is learning with VR technology more interesting, helpful and easy learning?

Table 4.11 Question 4 Response

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

Converting the score into percentage:

$$P = \frac{4,5}{50} \times 100\% = 90\%$$

Therefore, it can be concluded that the VR application helps people find interest, help, and ease in using VR technology as a learning medium.

5. Can learning and training using VR be delivered and be a complement to face-to-face learning?

Table 4.12 Question 5 Response

Score	Respondent	Total Score
5	4	20
4	5	20
3	1	3
2	0	0

1	0	0
Total	10	43
Total Average Score		4,3

Converting the score into percentage:

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

Therefore, it can be concluded that the VR application can be a complement to face-to-face learning.

6. Does the inspection training using VR adequately illustrate hands-on learning on board?

Table 4.13 Question 6 Response

Score	Respondent	Total Score
5	5	25
4	4	16
3	1	3
2	0	0
1	0	0
Total	10	44
Total Average Score		4,4

Converting the score into percentage:

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

Therefore, it can be concluded that the VR application has illustrated hands-on learning onboard adequately.

7. If you are inspection survey trainee / marine student / other marine practitioner, has the application delivered MLC, 2006 training inspection materials well?

Table 4.14 Question 7 Response

Score	Respondent	Total Score
5	2	10
4	3	12
3	2	6
2	0	0
1	0	0
Total	7	28
Total Average Score		4,0

Converting the score into percentage:

$$P = \frac{28}{35} \times 100\% = 80\%$$

Therefore, it can be concluded that the VR application has delivered MLC, 2006 training inspection materials well.

8. If you are inspection survey trainee / marine student / other marine practitioner, is this application helpful for inspection training purposes?

Table 4.15 Question 8 Response

Score	Respondent	Total Score
5	3	15
4	3	12
3	1	3
2	0	0
1	0	0
Total	7	30
Total Average Score		4,3

Converting the score into percentage:

$$P = \frac{30}{35} \times 100\% = 86\%$$

Therefore, it can be concluded that the VR application is helpful for inspection training purposes.

Based on the percentage obtained through the calculation of the questionnaire for each question, then scoring summary is as shown in Table 4.16:

Table 4.16 User Assessment Score Summary

Question No.	Percentage Value	Total Score
1	80%	40
2	76%	38
3	76%	38
4	90%	45
5	86%	43
6	88%	44
7	80%	40
8	86%	43
Total Score		331
Total Average Score		4.1

To obtain the quantitative score of the VR application based on the user assessment, the steps are as follows:

1. Determine the Maximum Score, by multiplying (largest answer score) by (total questions) and (total respondents).
$$Max = 5 \times 8 \times (10\ Respondents) = 400$$

2. Determine the Minimum Score, by multiplying (smallest answer score) by (total questions), and (total respondents).
$$Min = 1 \times 8 \times (10\ Respondents) = 80$$

3. Determine the Median value, by dividing the sum of (maximum total score) and (minimum total score) into two.
$$Med = \frac{(400 + 80)}{2} = 240$$

4. Determine the Quartile I value, by dividing the sum of (median) and (minimum total score) into two.

$$Q_1 = \frac{(240 + 80)}{2} = 160$$

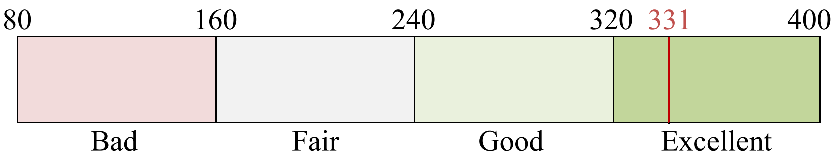
5. Determine the Quartile III value, by dividing the sum of (maximum score) and (median) into two.

$$Q_3 = \frac{(400 + 240)}{2} = 320$$

Table 4.16 shows the quantitative rubric assessment as categorized based on the value of Maximum score, Quartile III, Median, Quartile I and Minimum score that have been obtained before.

Table 4.17 Quantitative Rubric Assessment

Category	**Description**	**Score**
Excellent	Quartile III ≤ x ≤ Maximum Score	320 – 400
Good	Median ≤ x < Quartile III	240 – 320
Fair	Quartile I ≤ x ≤ Median	160 – 240
Bad	Minimum Score ≤ x ≤ Quartile I	80 – 160



Based on the user assessment, it can be concluded that this Virtual Reality Application for MLC, 2006 Inspection Training has scored 331 out of 400 which is in the **excellent** category.

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CHAPTER V
CONCLUSION

5.1 Conclusion

This study has produced a VR application that is intended to be used for surveyors and other marine practitioner to help them understand more or being introduced to MLC, 2006 inspection. The VR application features a virtual environment that has been modelled after a real ship owned by PT. Meratus Line, named MV. Meratus Benoa, especially the accommodation area. The ship has 5 decks in the accommodation area which are: Wheelhouse, Deck A (where Captain and Chief Engineer's Room are at), Upper Forecastle Deck, Lower Forecastle Deck, and Main Deck. The ship has 15 personnels onbard, however for this application only 5 that are the most representative are made and functioned as NPC for the game mode. The VR application also features a tab that contains a guiding checklist which contents are taken from MLC, 2006 that has been analyzed by Lloyd Register.

The objective of this research is to create a VR application that can accommodate the needs of inspection training in compliance with MLC. 2006 that is safe and economical. Based on the user assessment that has been analyzed, this VR application has achieved its objective and the proof can be seen by the its assessment score which is 331 out of 400, which indicates that this VR application is of excellent category. But there is still a plenty of room in this subject that can be explored and developed further.

5.2 Suggestion

From this research a few suggestions are made regarding this thesis, as follows:

1. There must be further development with more open, expansive, and imaginative features that can accommodate more flexible needs and attract more user
2. To get better quality product, better devices is needed to accommodate higher graphic/virtual requirement
3. For inspection training and study purpose, higher quality VR devices are needed to minimize motion sickness

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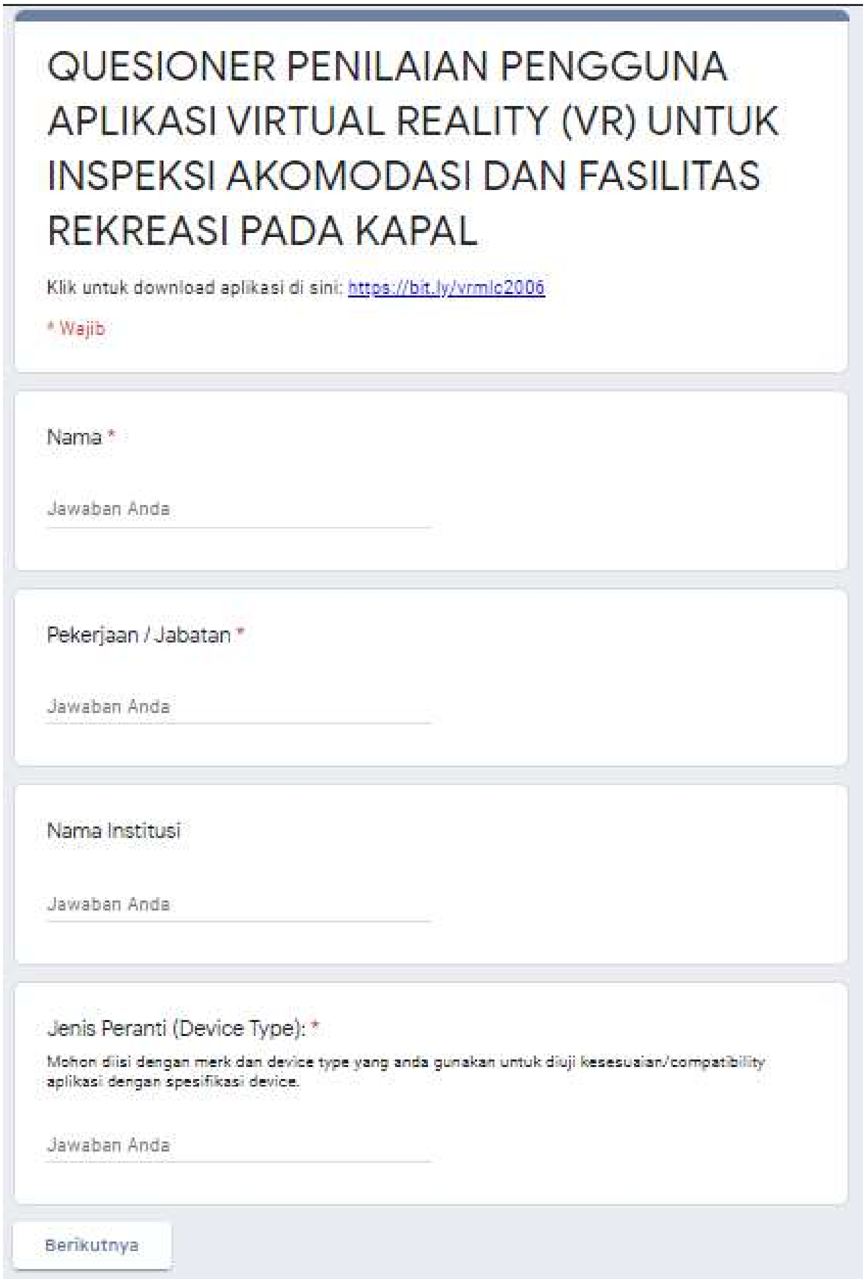
APPENDIX

USER ASSESSMENT QUESTIONNAIRE VIA GOOGLE FORM



QUESIONER PENILAIAN PENGGUNA APLIKASI VIRTUAL REALITY (VR) UNTUK INSPEKSI AKOMODASI DAN FASILITAS REKREASI PADA KAPAL

Klik untuk download aplikasi di sini: https://bit.ly/vrmlc2006

* Wajib

Nama *

Jawaban Anda

Pekerjaan / Jabatan *

Jawaban Anda

Nama Institusi

Jawaban Anda

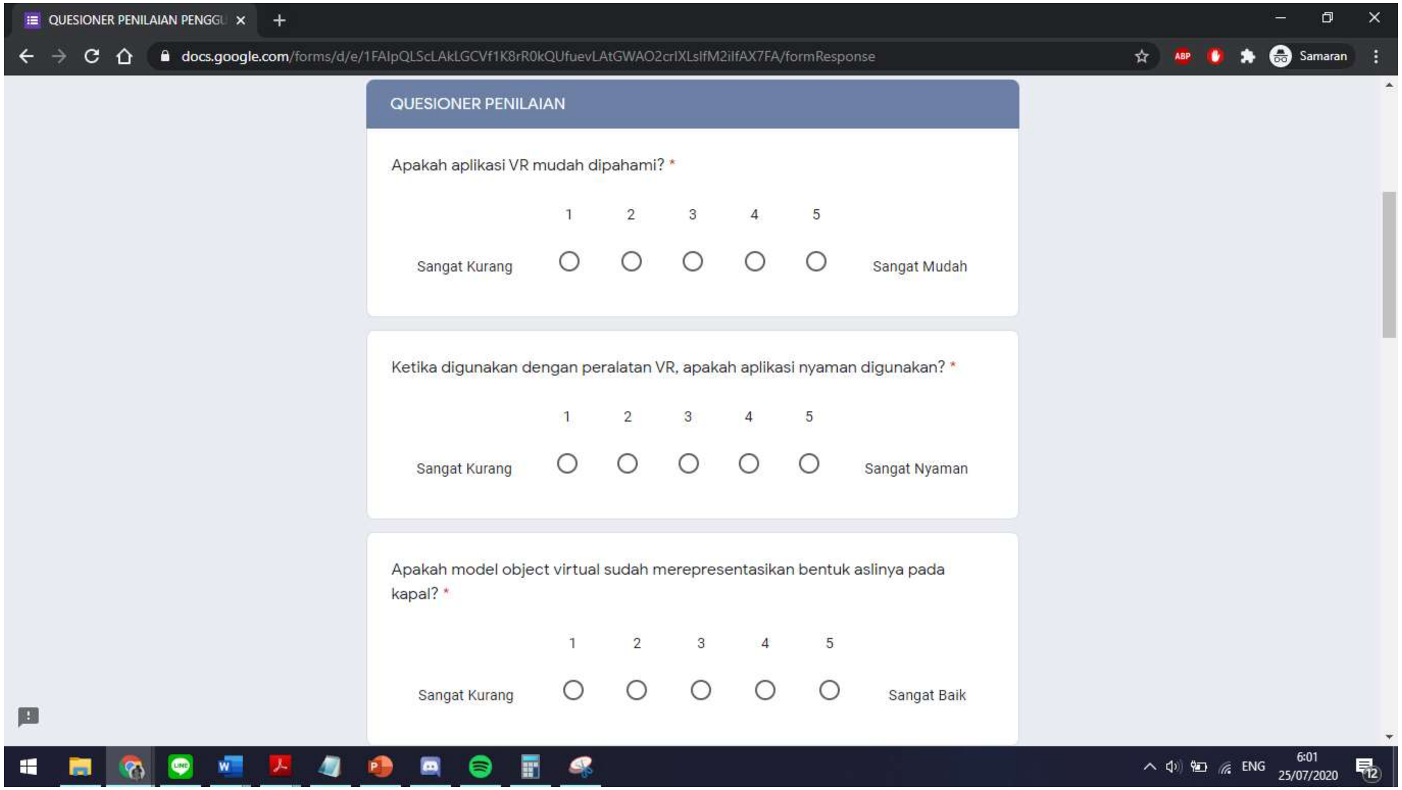
Jenis Peranti (Device Type): *

Mohon diisi dengan merk dan device type yang anda gunakan untuk diuji kesesuaian/compatibility aplikasi dengan spesifikasi device.

Jawaban Anda

Berikutnya

USER ASSESSMENT QUESTIONNAIRE VIA GOOGLE FORM



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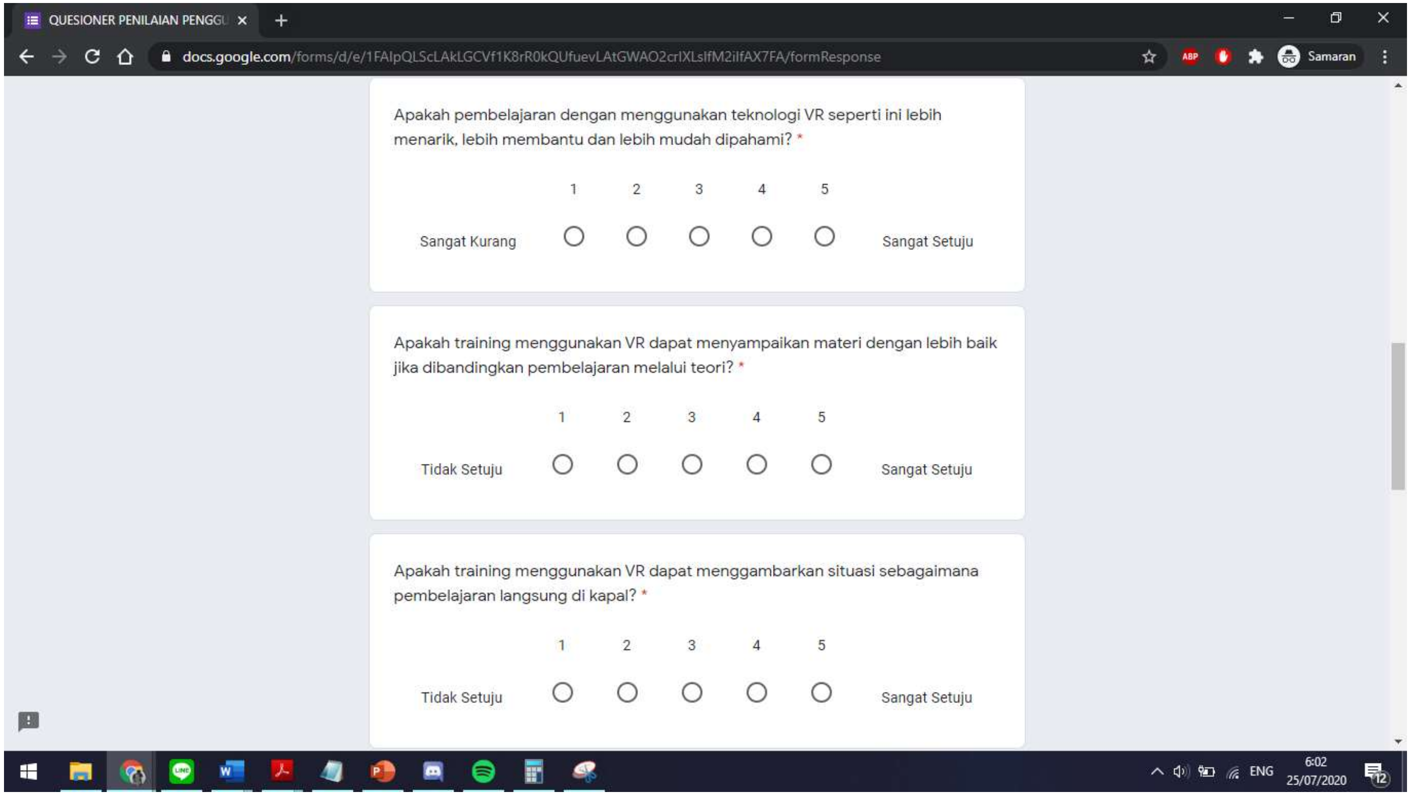

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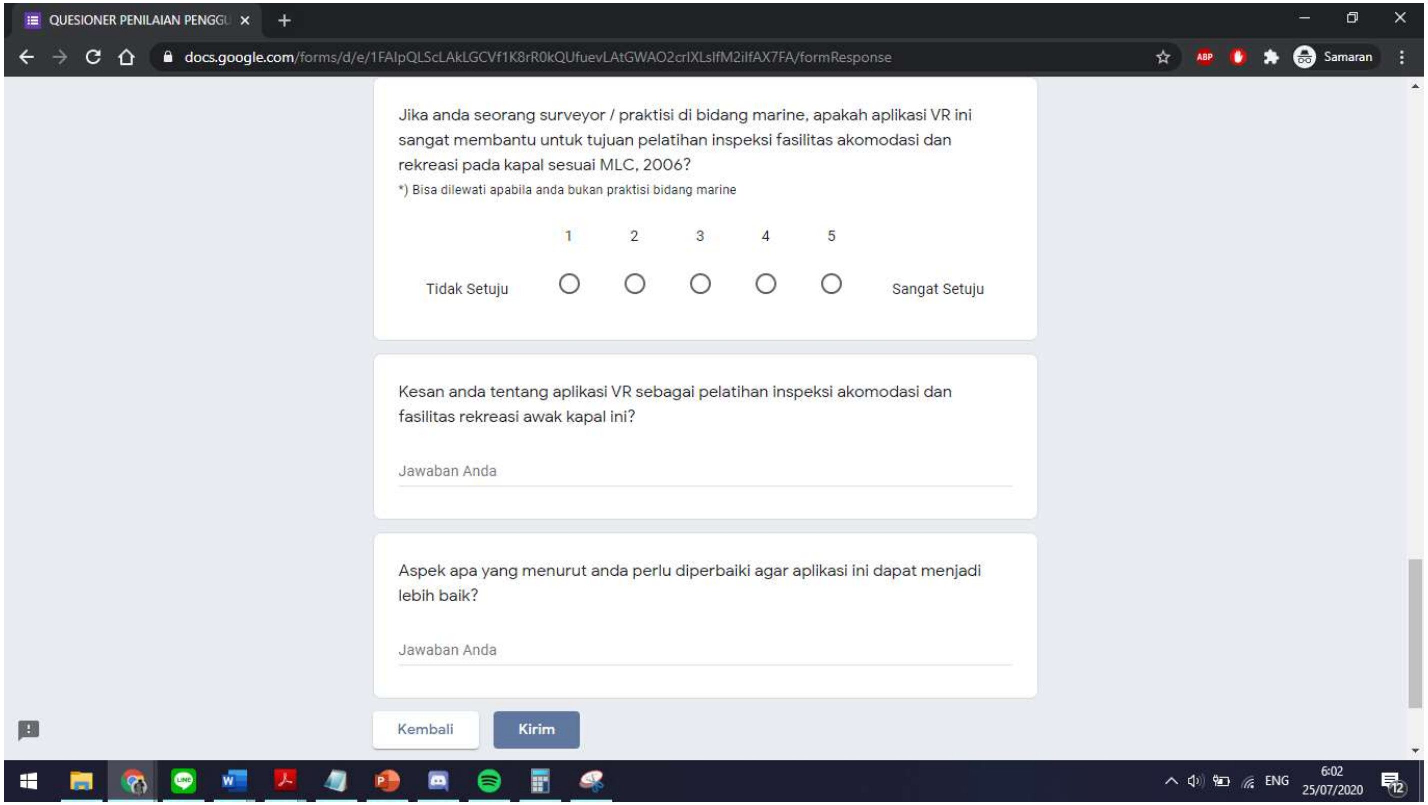

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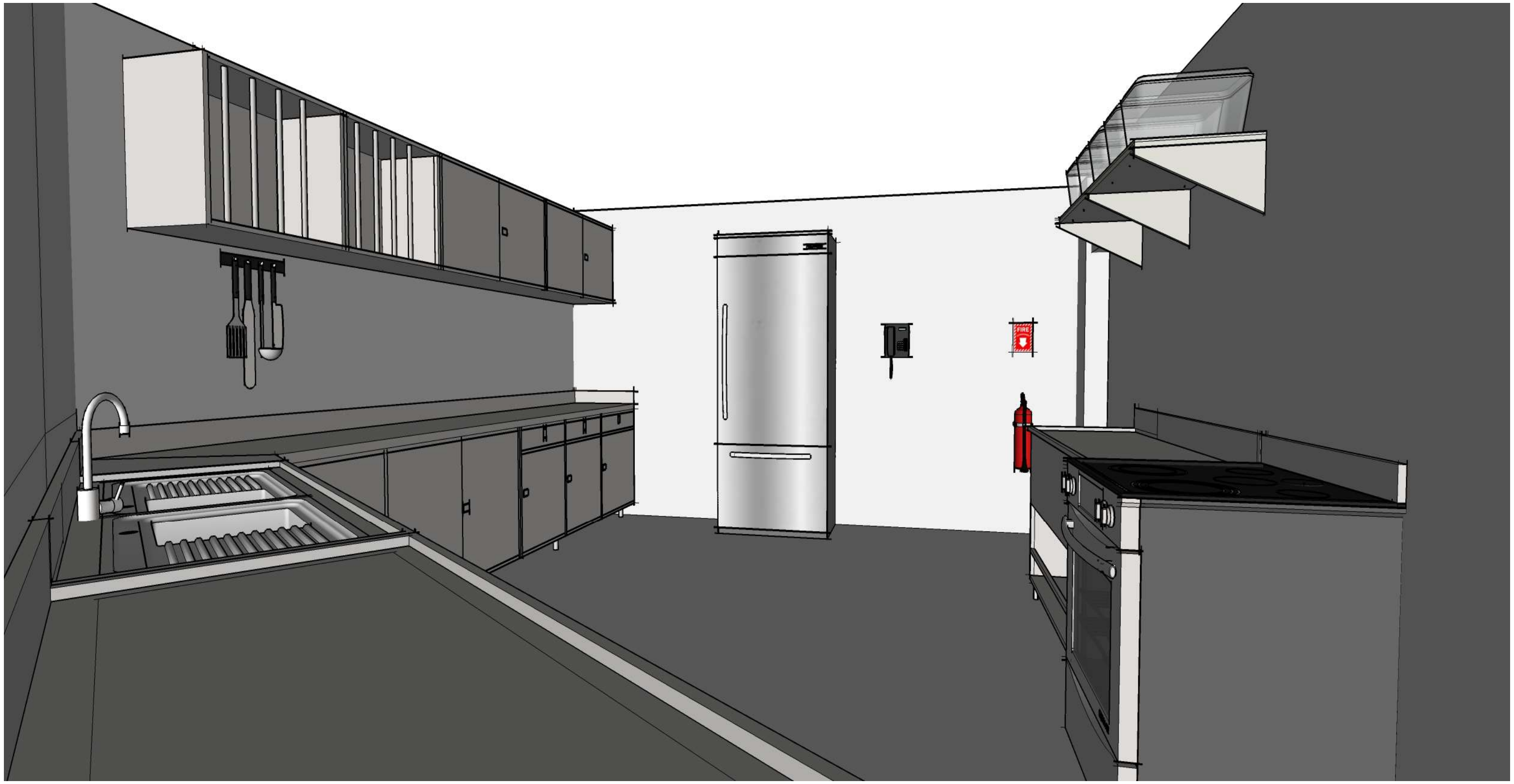
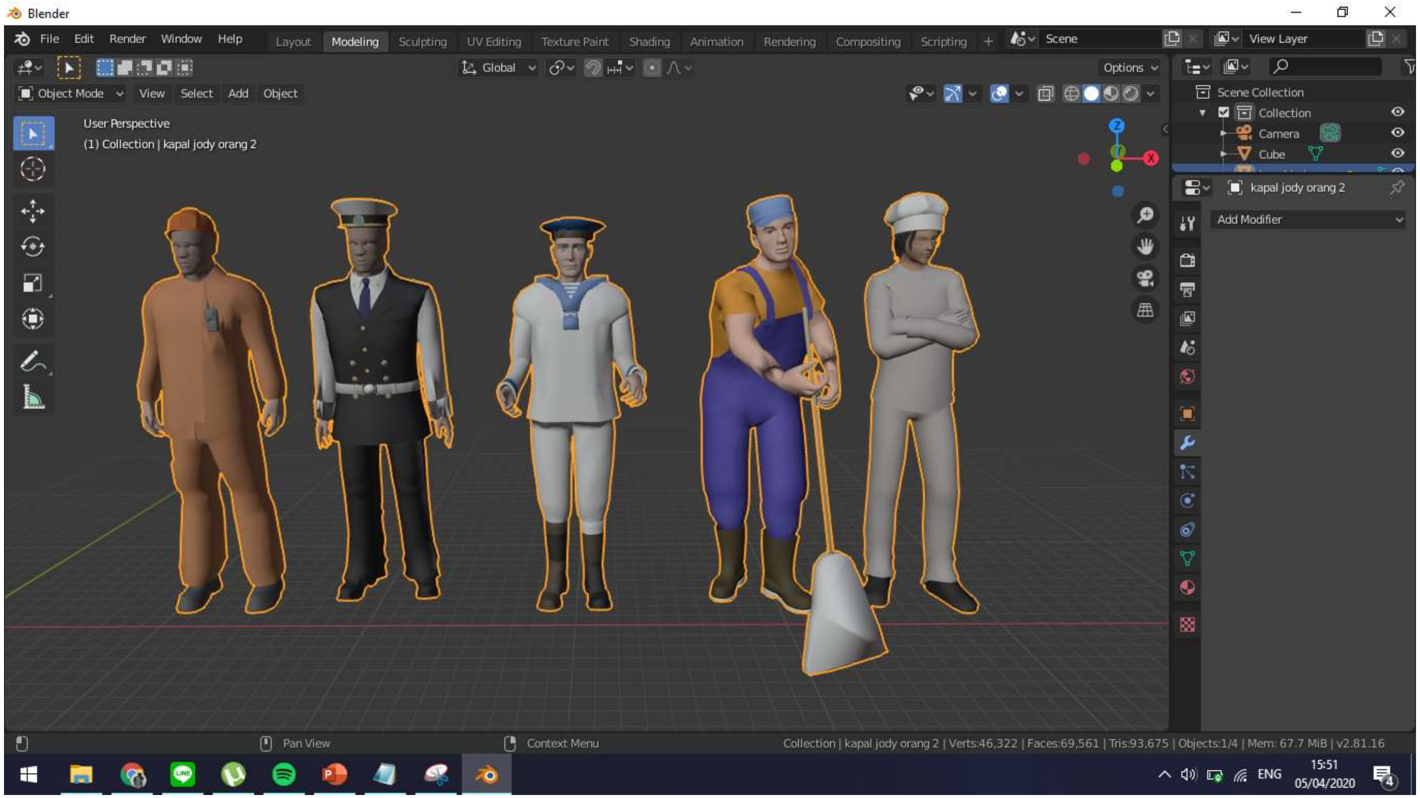
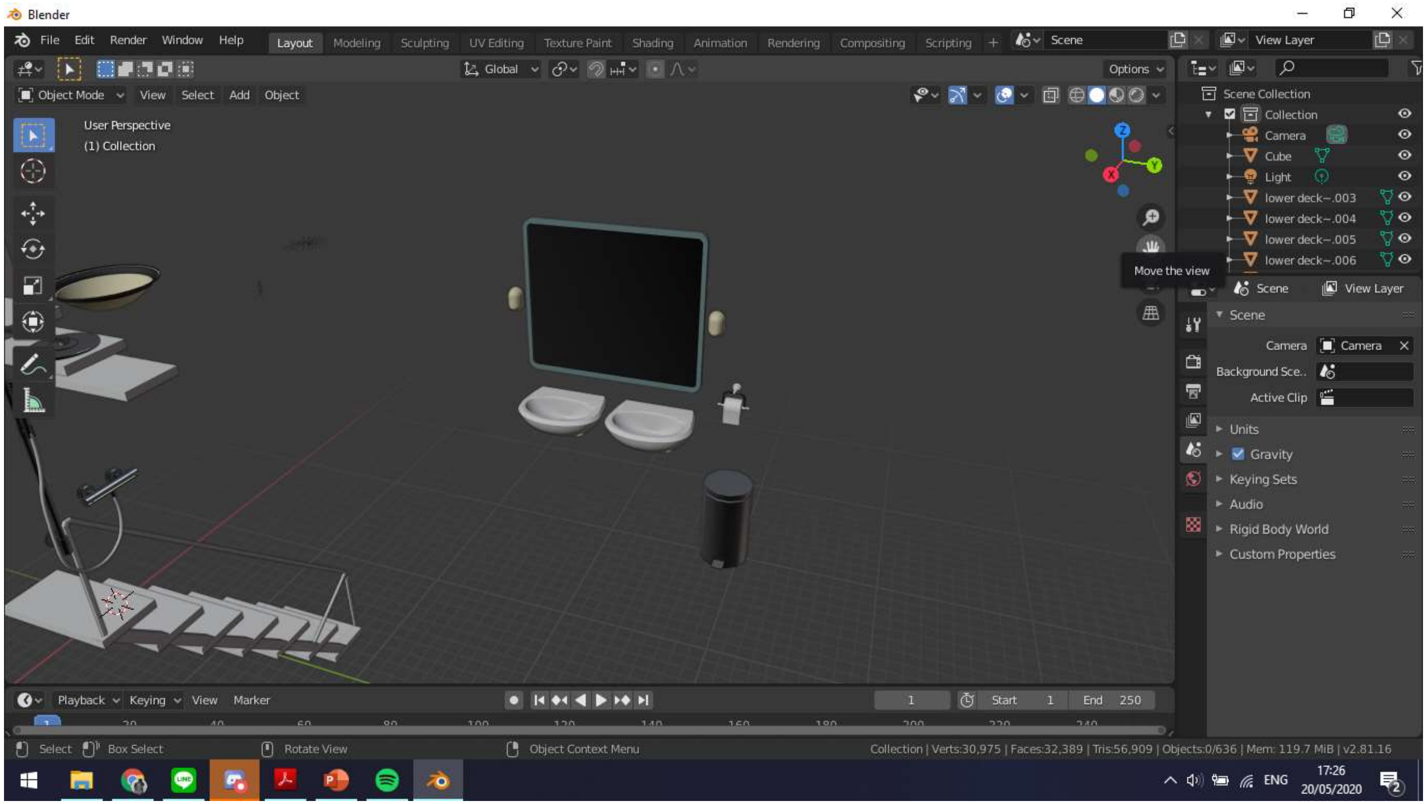
3D MODELLING INITIAL SKETCH



3D MODELLING USING BLENDER SOFTWARE

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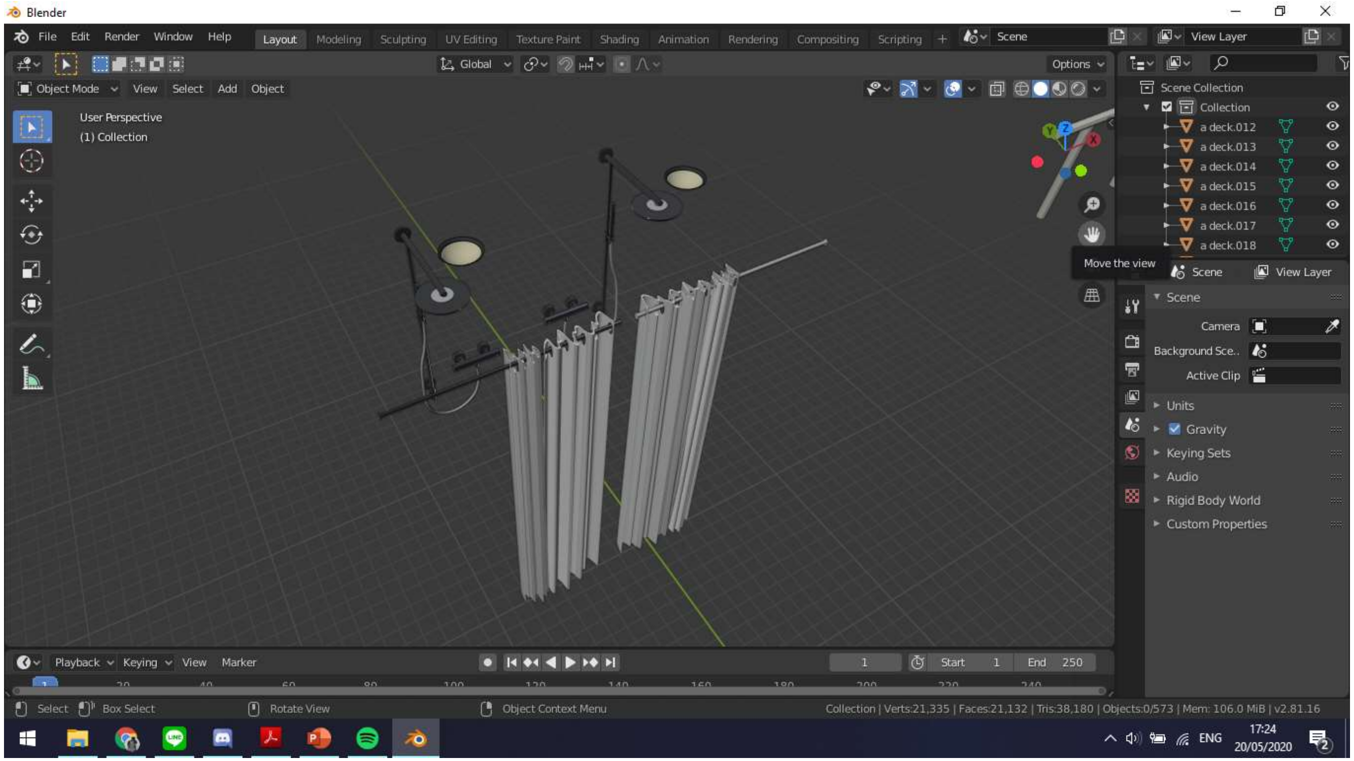
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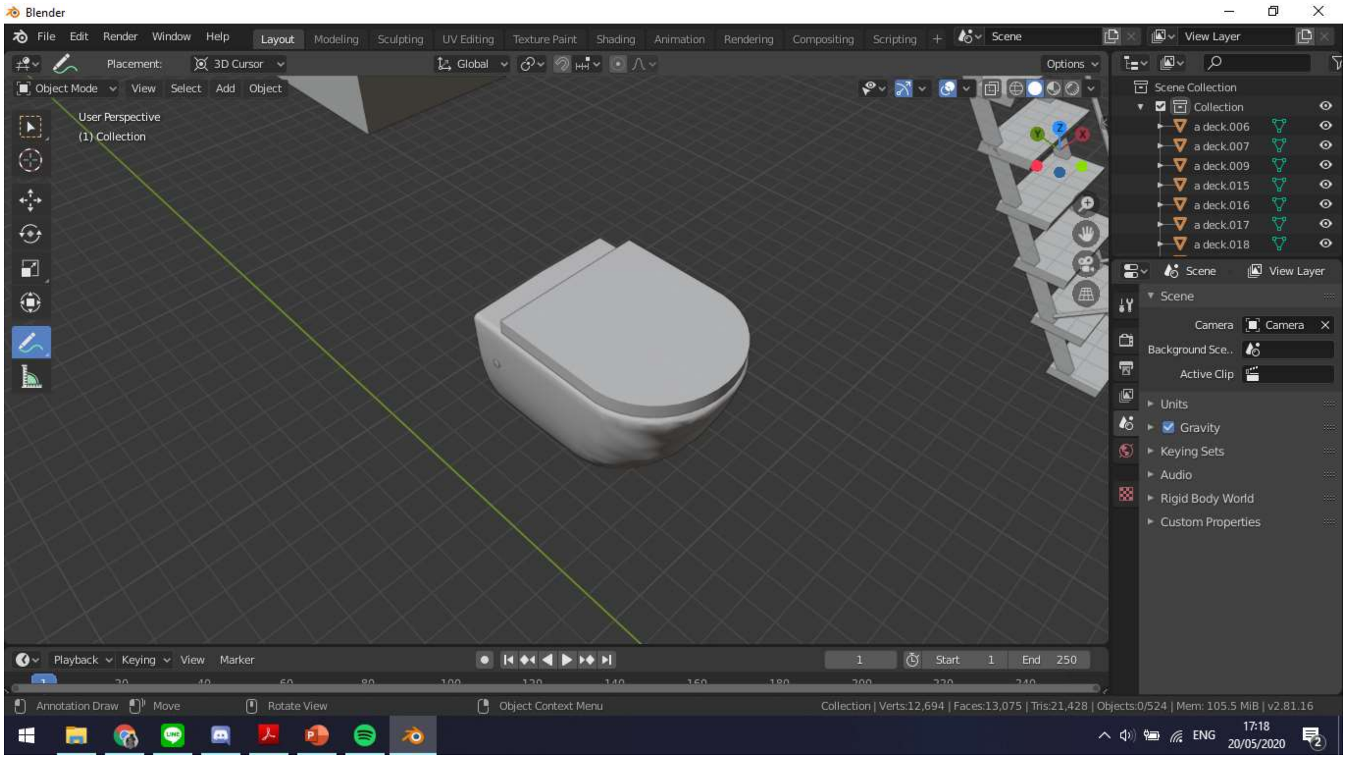
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User Perspective
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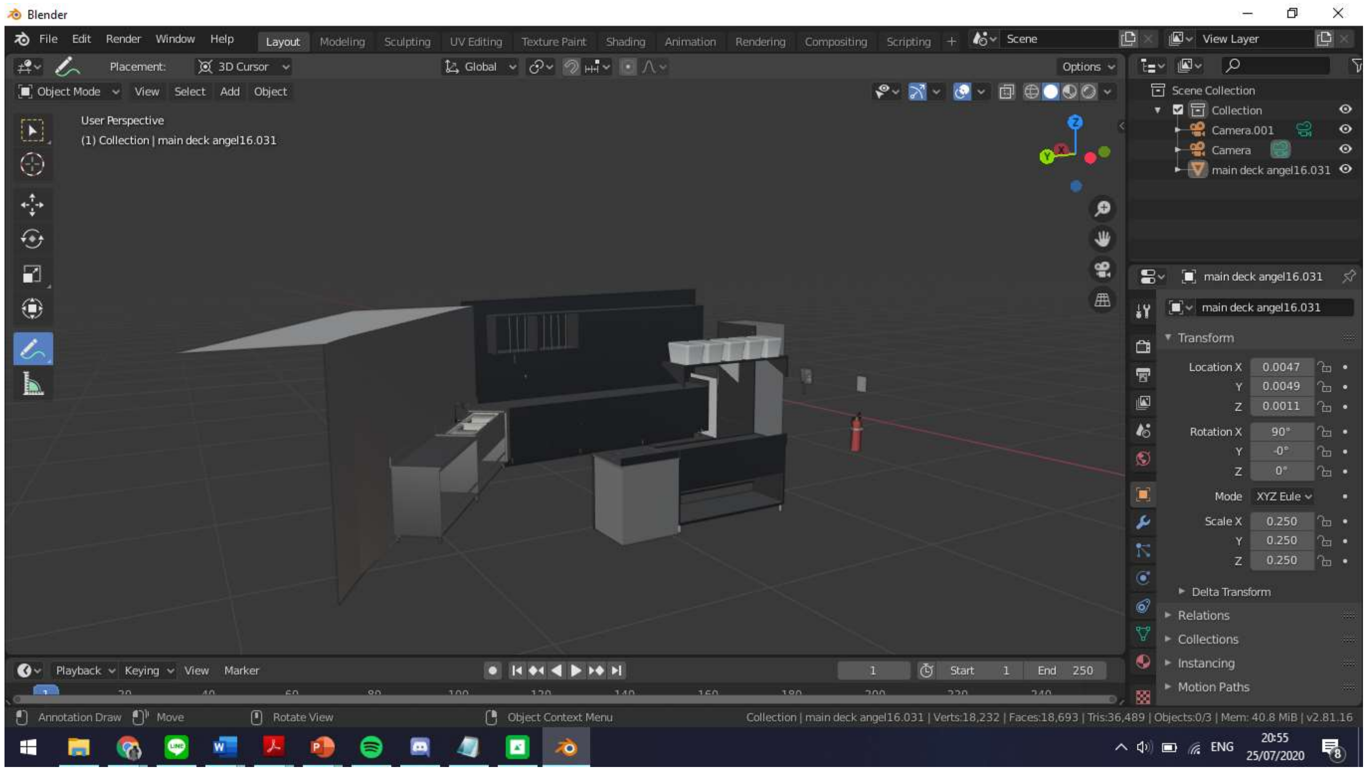
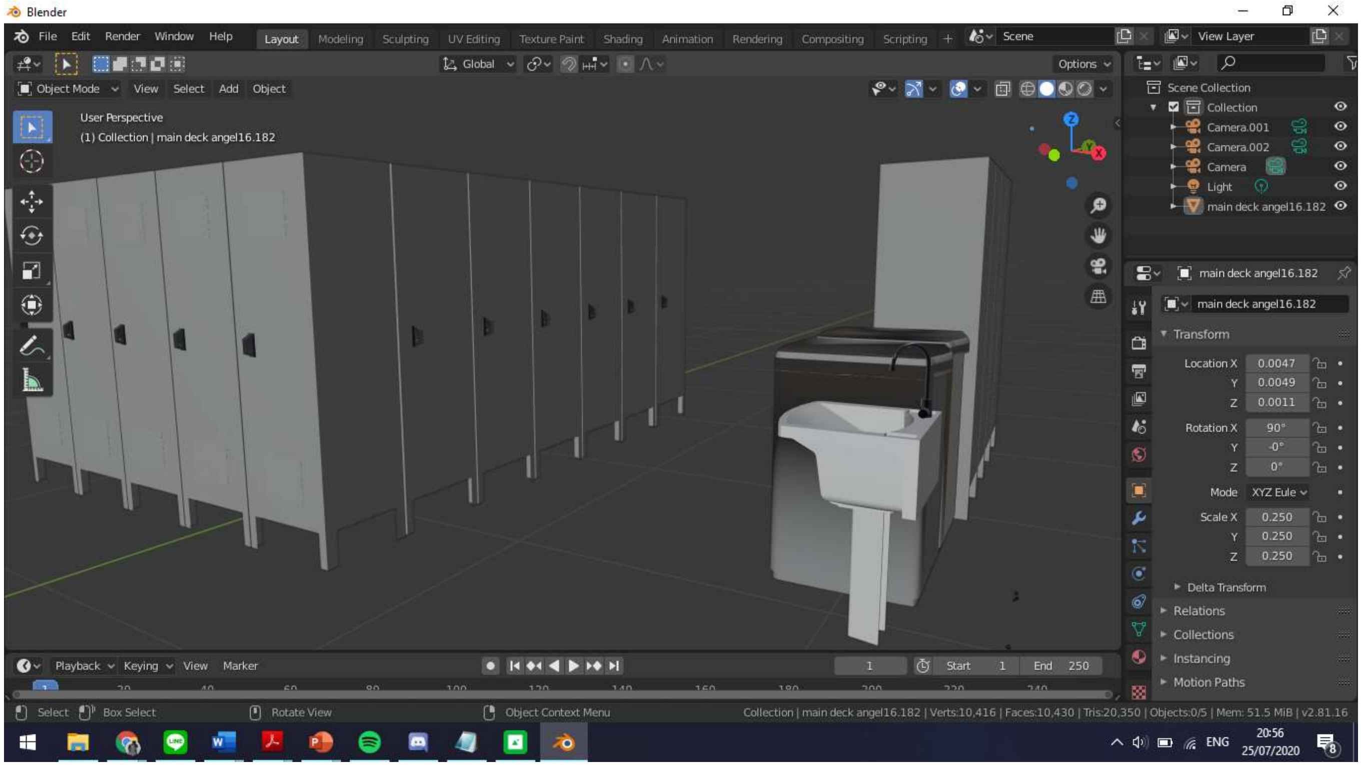
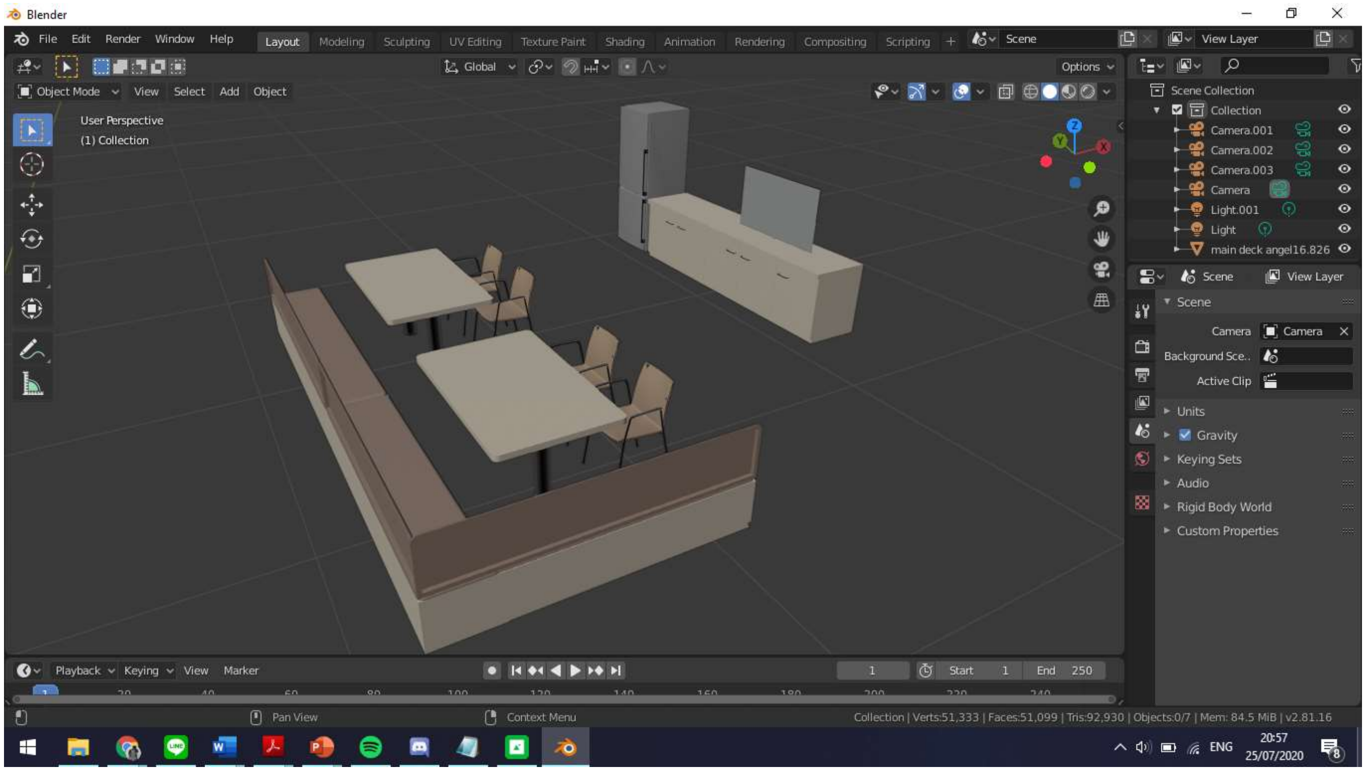
Rotate View
Object Context Menu
Collection | Verts:12,694 | Faces:13,075 | Tris:21,428 | Objects:0/524 | Mem: 105.5 MiB | v2.81.16
ENG
17:18
20/05/2020

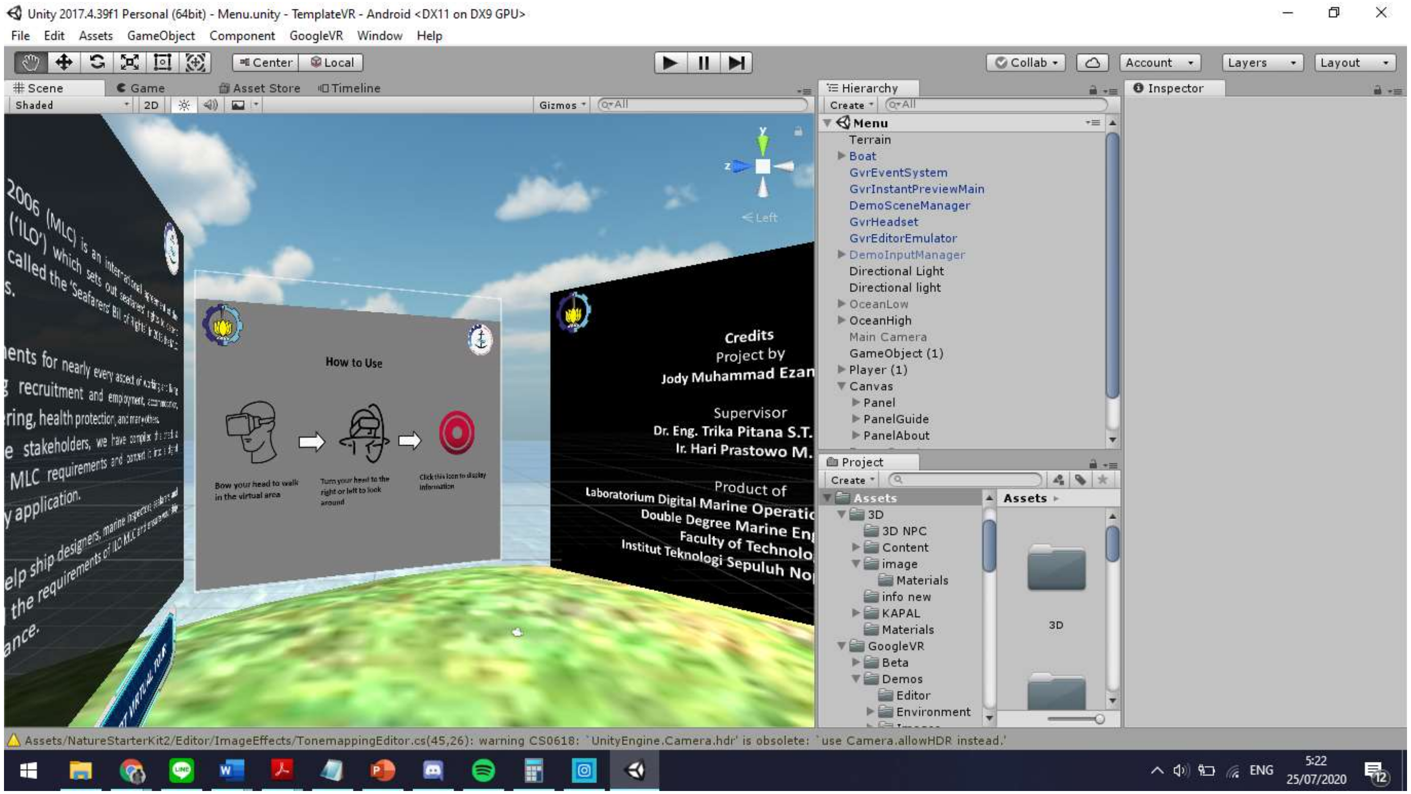
3D MODELLING USING BLENDER SOFTWARE

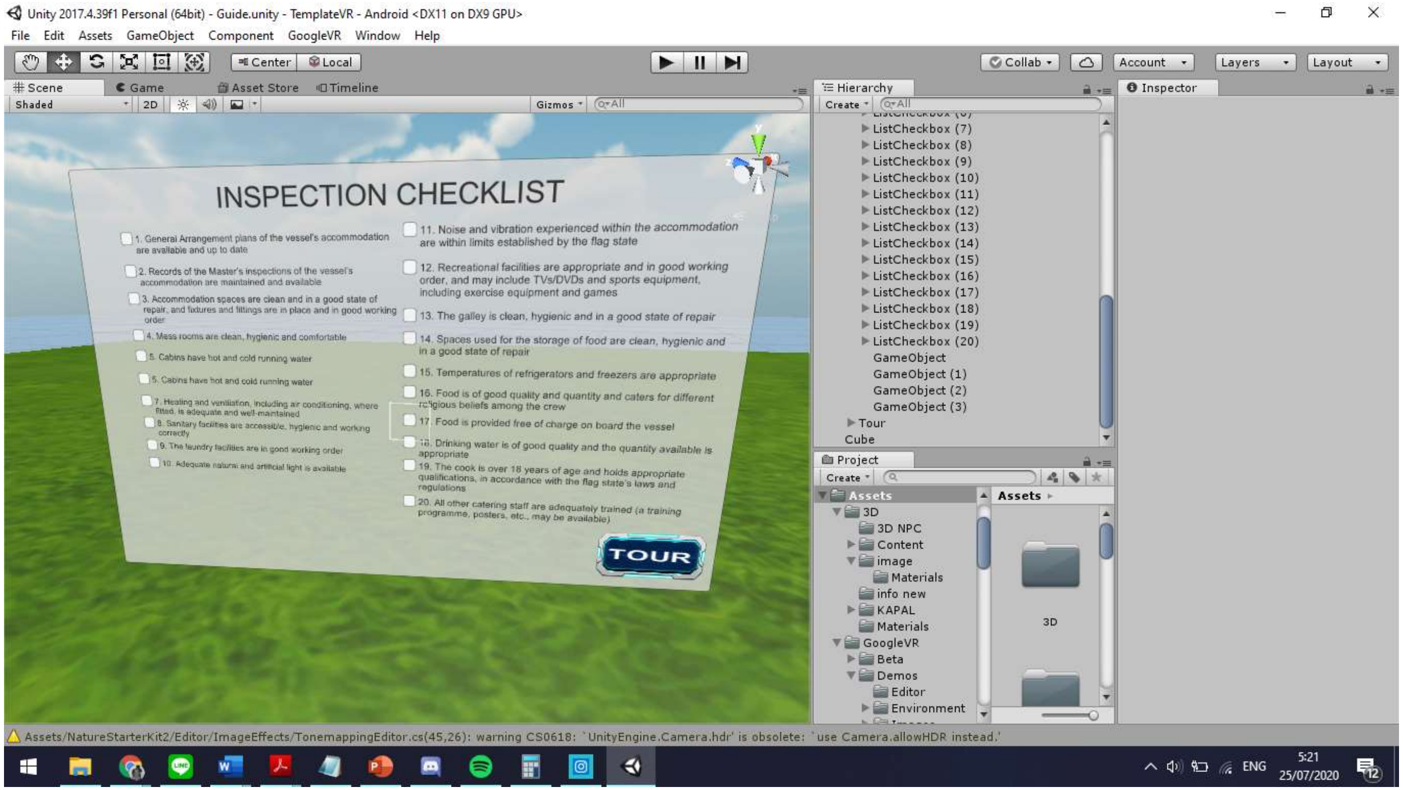


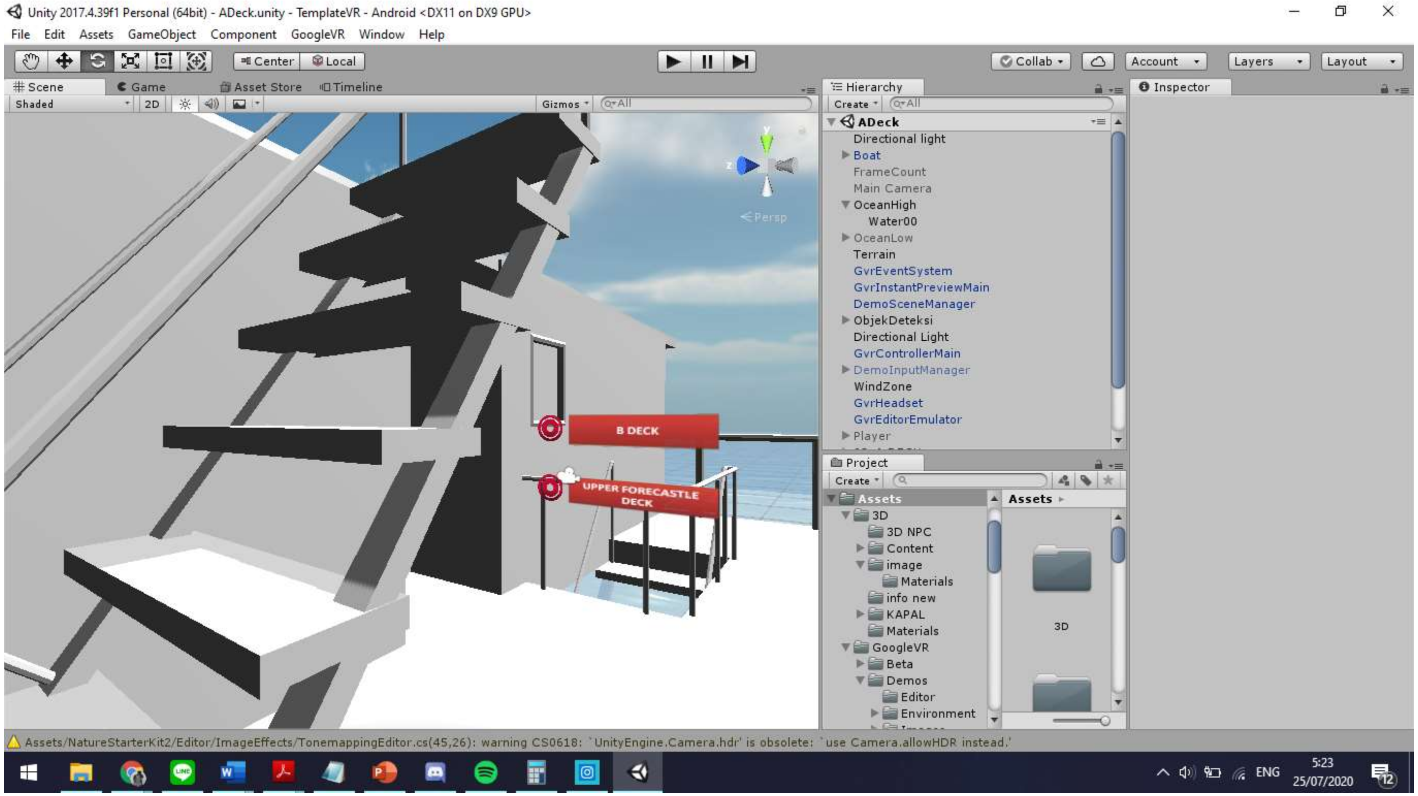

Blender
File Edit Render Window Help
Layout Modeling Sculpting UV Editing Texture Paint Shading Animation Rendering Compositing Scripting
Scene
View Layer
Global
Options
Object Mode View Select Add Object
User Perspective
(1) Collection | main deck angel16.182
Scene Collection
Collection
Camera.001
Camera.002
Camera
Light
main deck angel16.182
Transform
Location X 0.0047
Y 0.0049
Z 0.0011
Rotation X 90°
Y -0°
Z 0°
Mode XYZ Eule
Scale X 0.250
Y 0.250
Z 0.250
Delta Transform
Relations
Collections
Instancing
Motion Paths
Playback Keying View Marker
Start 1 End 250
Select Box Select Rotate View Object Context Menu
Collection | main deck angel16.182 | Verts:10,416 | Faces:10,430 | Tris:20,350 | Objects:0/5 | Mem: 51.5 MiB | v2.81.16
ENG
20:56
25/07/2020

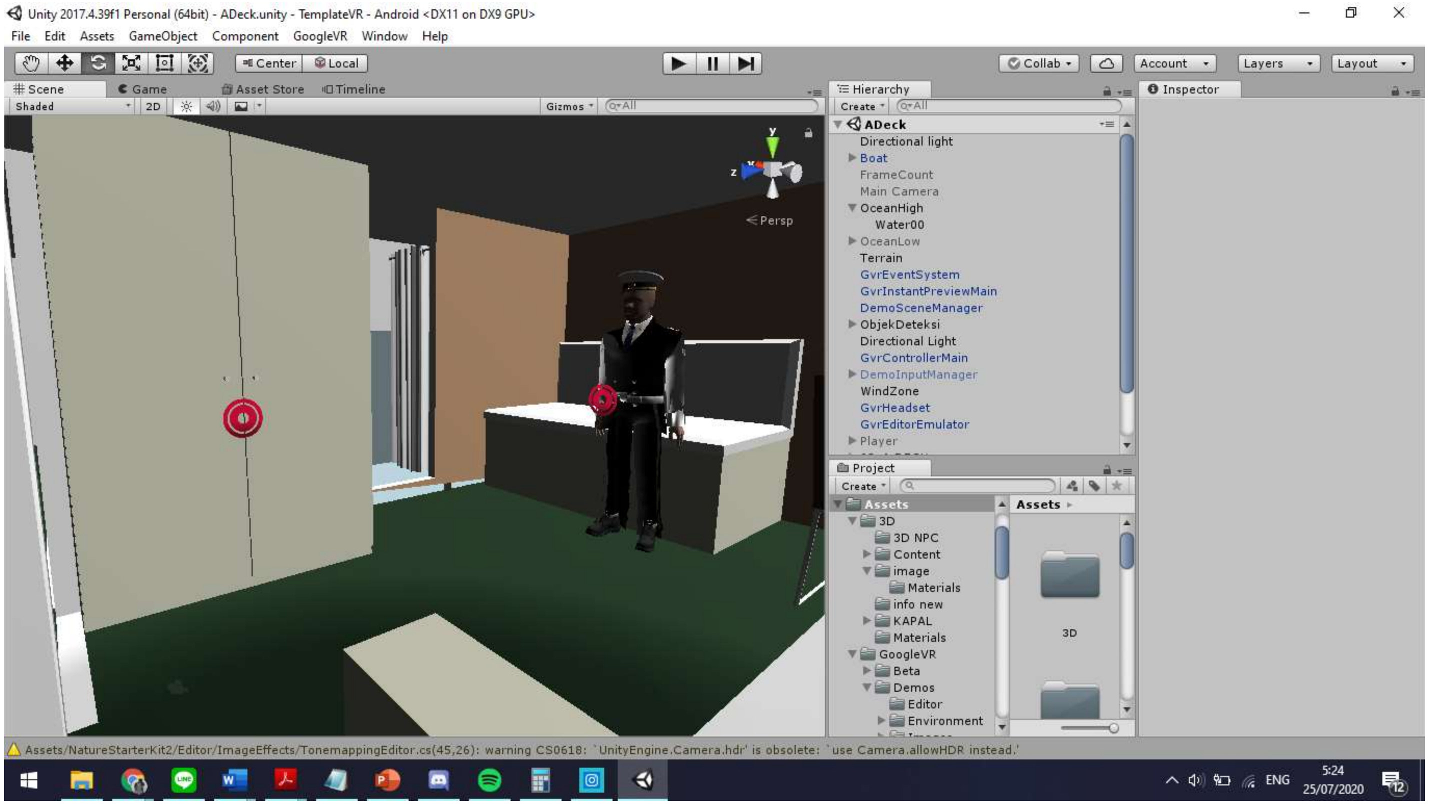

Blender
File Edit Render Window Help
Layout Modeling Sculpting UV Editing Texture Paint Shading Animation Rendering Compositing Scripting
Scene
View Layer
Global
Options
Object Mode View Select Add Object
User Perspective
(1) Collection
Scene Collection
Collection
Camera.001
Camera.002
Camera.003
Camera
Light.001
Light
main deck angel16.826
Scene
View Layer
Scene
Camera
Camera
Background Sce..
Active Clip
Units
Gravity
Keying Sets
Audio
Rigid Body World
Custom Properties
Playback Keying View Marker
1
Start 1
End 250
Pan View
Context Menu
Collection | Verts:51,333 | Faces:51,099 | Tris:92,930 | Objects:0/7 | Mem: 84.5 MiB | v2.81.16
ENG
20:57
25/07/2020

VIRTUAL REALITY DEVELOPMENT USING UNITY 3D SOFTWARE




Unity 2017.4.39f1 Personal (64bit) - Guide.unity - TemplateVR - Android <DX11 on DX9 GPU>
File Edit Assets GameObject Component GoogleVR Window Help
Center Local
Collab Account Layers Layout
Scene Game Asset Store Timeline
Shaded 2D Gizmos
Hierarchy
Create
ListCheckbox (7)
ListCheckbox (8)
ListCheckbox (9)
ListCheckbox (10)
ListCheckbox (11)
ListCheckbox (12)
ListCheckbox (13)
ListCheckbox (14)
ListCheckbox (15)
ListCheckbox (16)
ListCheckbox (17)
ListCheckbox (18)
ListCheckbox (19)
ListCheckbox (20)
GameObject
GameObject (1)
GameObject (2)
GameObject (3)
Tour
Cube
Inspector
Project
Assets
3D
3D NPC
Content
image
Materials
info new
KAPAL
Materials
GoogleVR
Beta
Demos
Editor
Environment
INSPECTION CHECKLIST
11. Noise and vibration experienced within the accommodation are within limits established by the flag state
12. Recreational facilities are appropriate and in good working order, and may include TVs/DVDs and sports equipment, including exercise equipment and games
13. The galley is clean, hygienic and in a good state of repair
14. Spaces used for the storage of food are clean, hygienic and in a good state of repair
15. Temperatures of refrigerators and freezers are appropriate
17. Food is provided free of charge on board the vessel
TOUR
Assets/NatureStarterKit2/Editor/ImageEffects/TonemappingEditor.cs(45,26): warning CS0618: `UnityEngine.Camera.hdr' is obsolete: `use Camera.allowHDR instead.'
ENG
5:21
25/07/2020


Unity 2017.4.39f1 Personal (64bit) - ADeck.unity - TemplateVR - Android <DX11 on DX9 GPU>
File Edit Assets GameObject Component GoogleVR Window Help
Center
Local
Collab
Account
Layers
Layout
Scene
Game
Asset Store
Timeline
Shaded
2D
Gizmos
Persp
B DECK
UPPER FORECASTLE DECK
Hierarchy
Create
ADeck
Directional light
Boat
FrameCount
Main Camera
OceanHigh
Water00
OceanLow
Terrain
GvrEventSystem
GvrInstantPreviewMain
DemoSceneManager
ObjekDeteksi
Directional Light
GvrControllerMain
DemoInputManager
WindZone
GvrHeadset
GvrEditorEmulator
Player
Inspector
Project
Create
Assets
3D
3D NPC
Content
image
Materials
info new
KAPAL
Materials
GoogleVR
Beta
Demos
Editor
Environment
Assets
3D
Assets/NatureStarterKit2/Editor/ImageEffects/TonemappingEditor.cs(45,26): warning CS0618: `UnityEngine.Camera.hdr' is obsolete: `use Camera.allowHDR instead.'
ENG
5:23
25/07/2020


Unity 2017.4.39f1 Personal (64bit) - ADeck.unity - TemplateVR - Android <DX11 on DX9 GPU>
File Edit Assets GameObject Component GoogleVR Window Help
Center
Local
Collab
Account
Layers
Layout
Scene
Game
Asset Store
Timeline
Shaded
2D
Gizmos
Persp
Hierarchy
Create
ADeck
Directional light
Boat
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ObjekDeteksi
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GvrControllerMain
DemoInputManager
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Player
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Project
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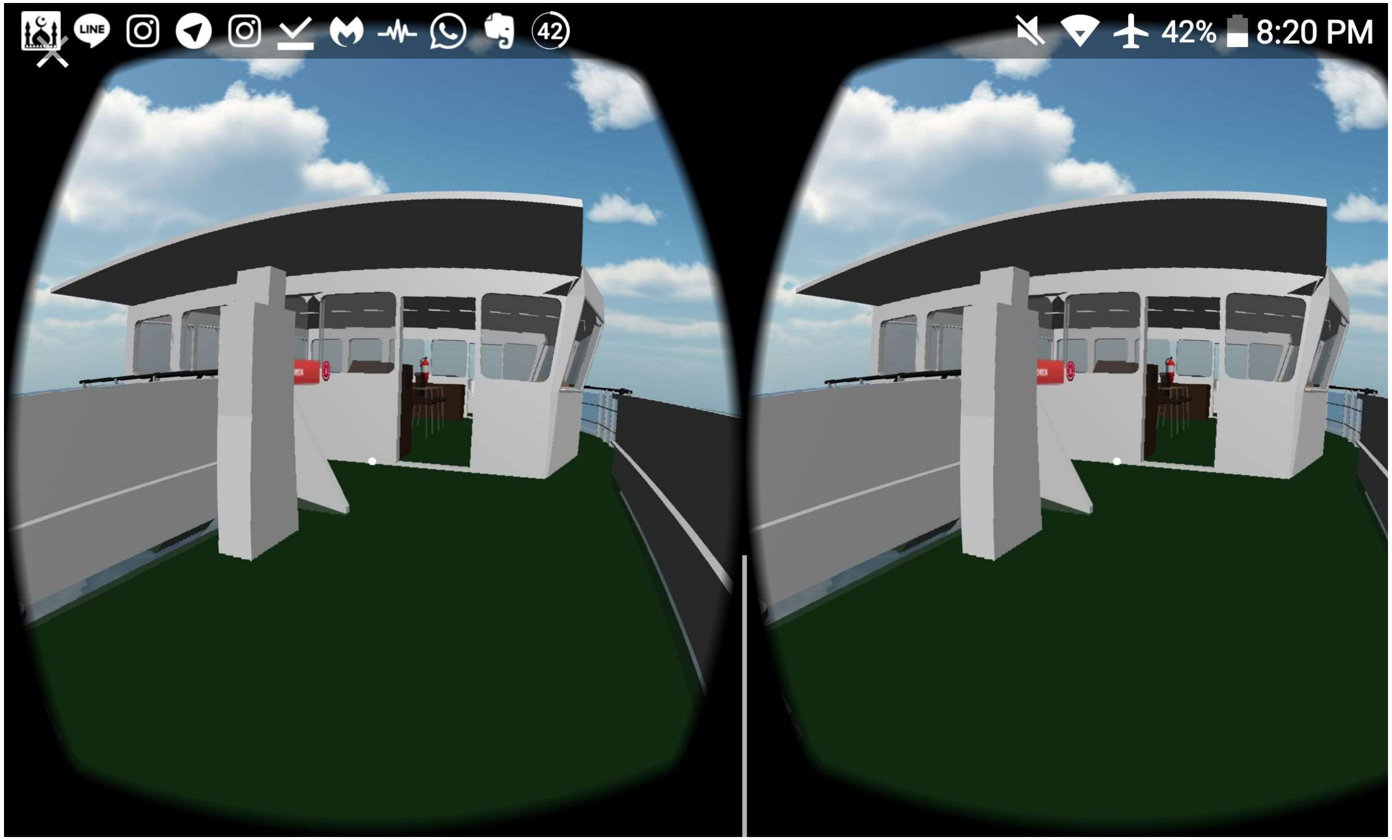
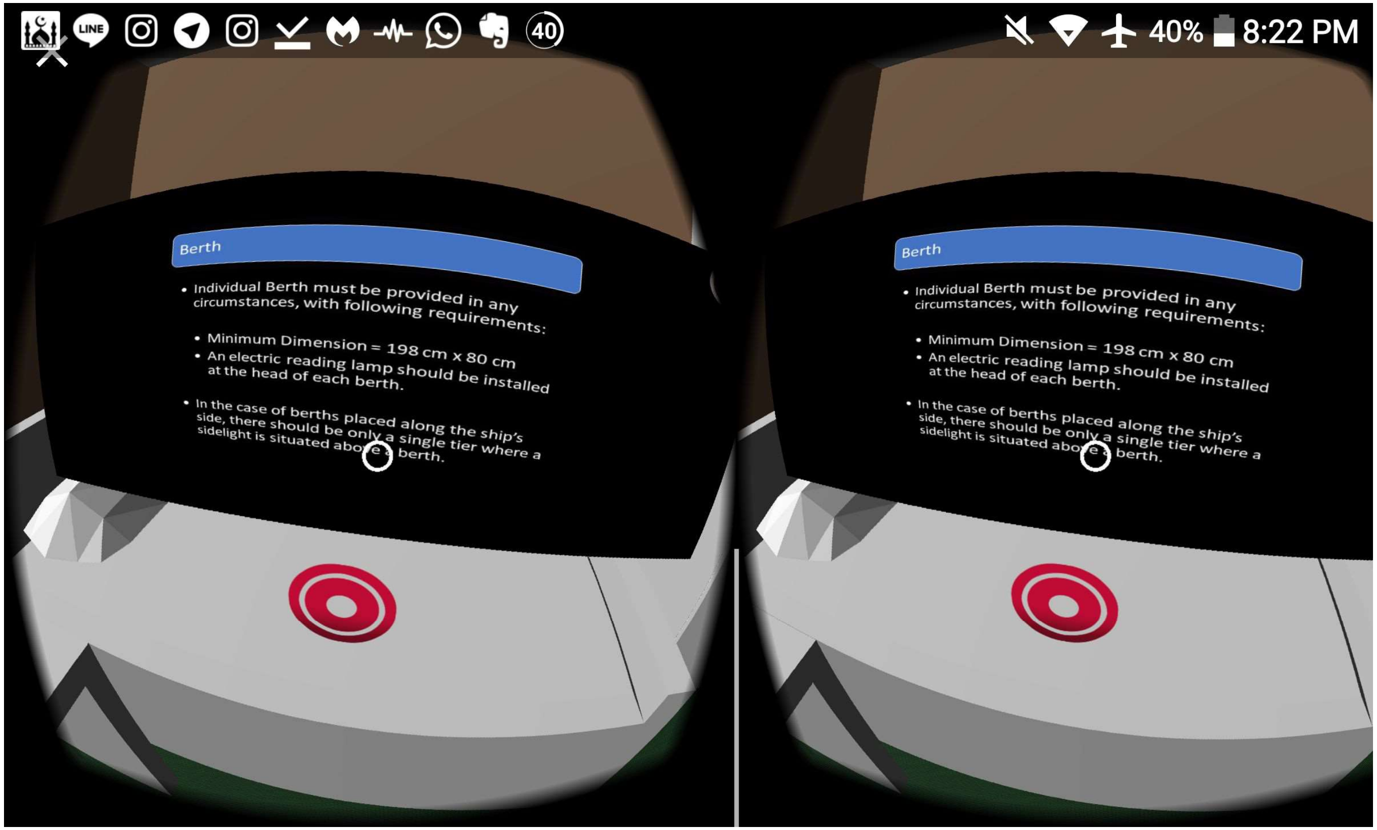
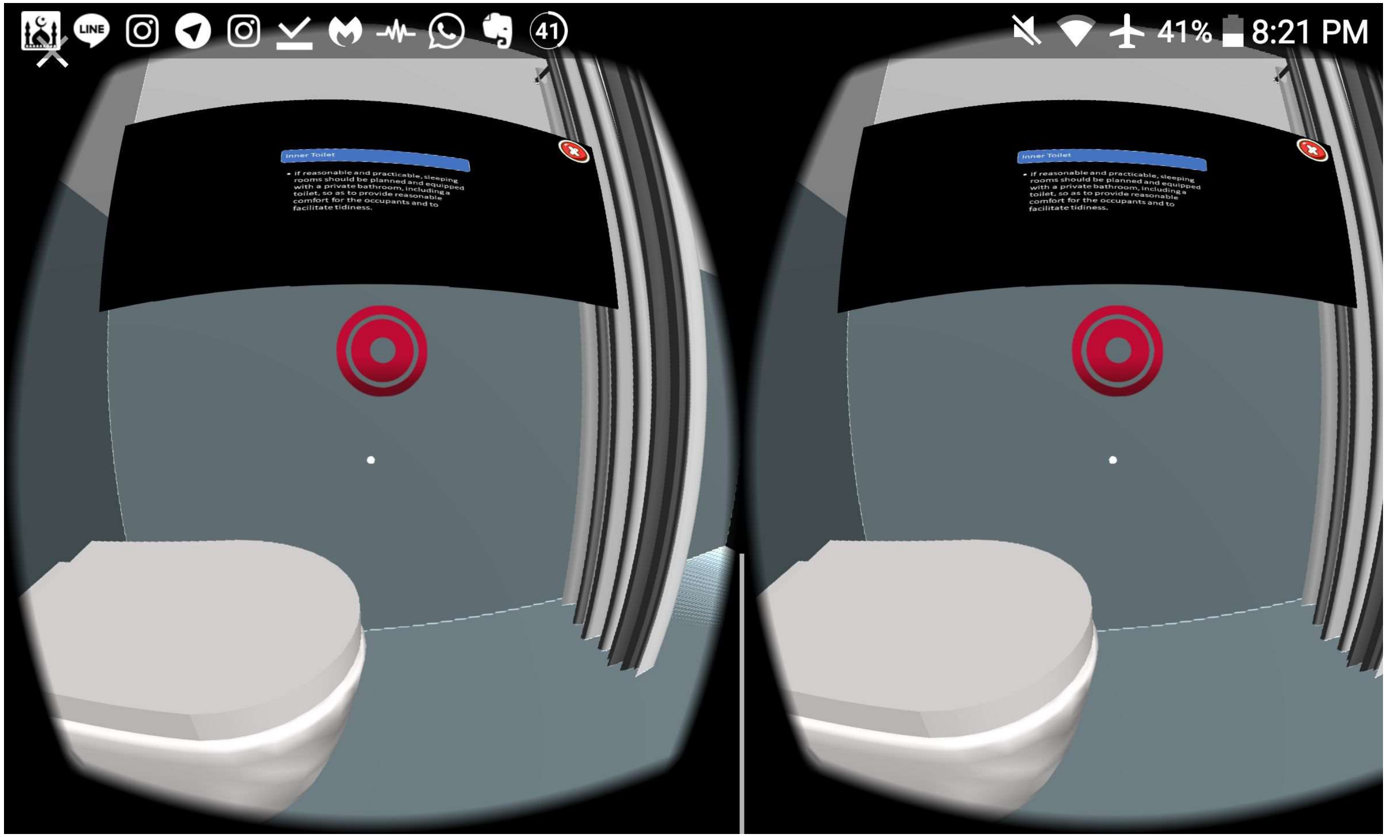
Assets
3D
3D NPC
Content
image
Materials
info new
KAPAL
Materials
GoogleVR
Beta
Demos
Editor
Environment
Assets
3D
Assets/NatureStarterKit2/Editor/ImageEffects/TonemappingEditor.cs(45,26): warning CS0618: `UnityEngine.Camera.hdr' is obsolete: `use Camera.allowHDR instead.'
ENG
5:24
25/07/2020

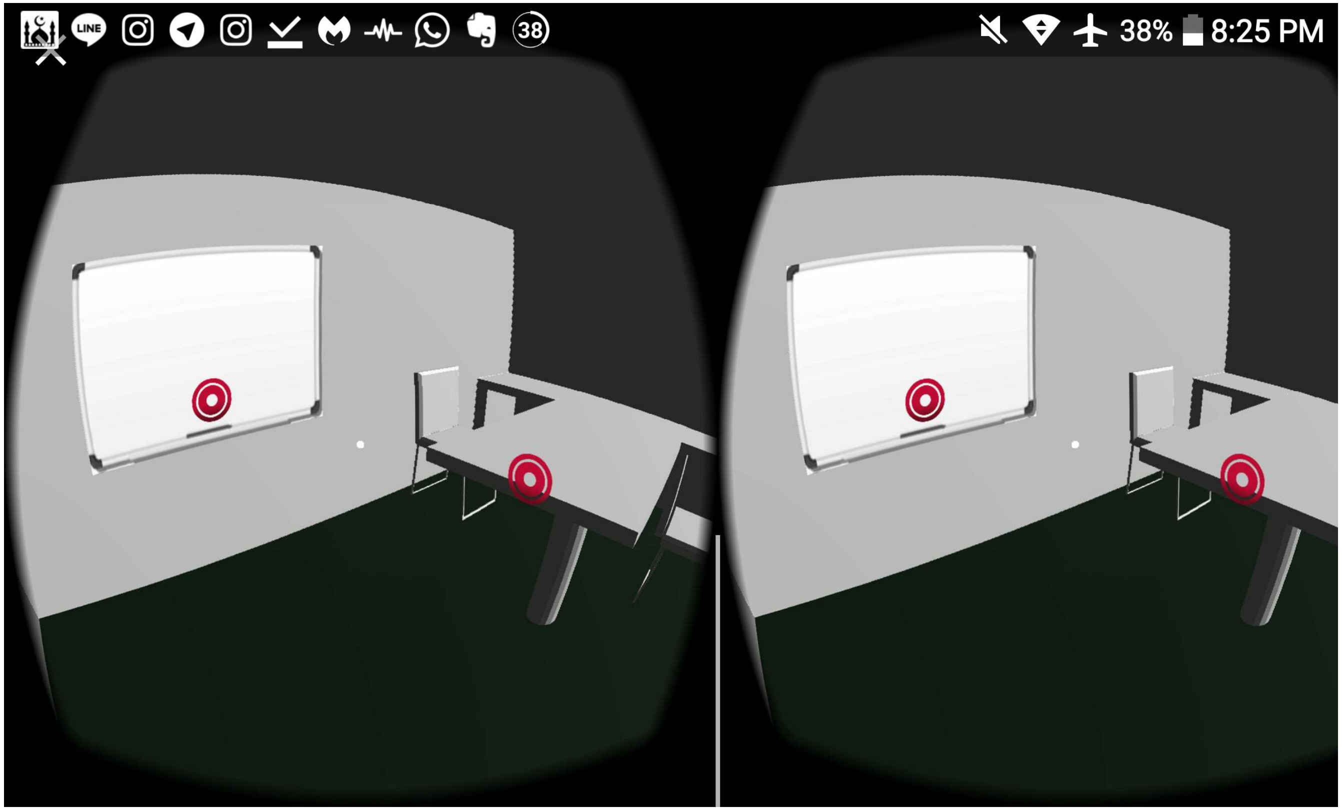

42
42%
8:20 PM


40% 8:22 PM
Berth
• Individual Berth must be provided in any circumstances, with following requirements:
• Minimum Dimension = 198 cm x 80 cm
• An electric reading lamp should be installed at the head of each berth.
• In the case of berths placed along the ship's side, there should be only a single tier where a sidelight is situated above a berth.

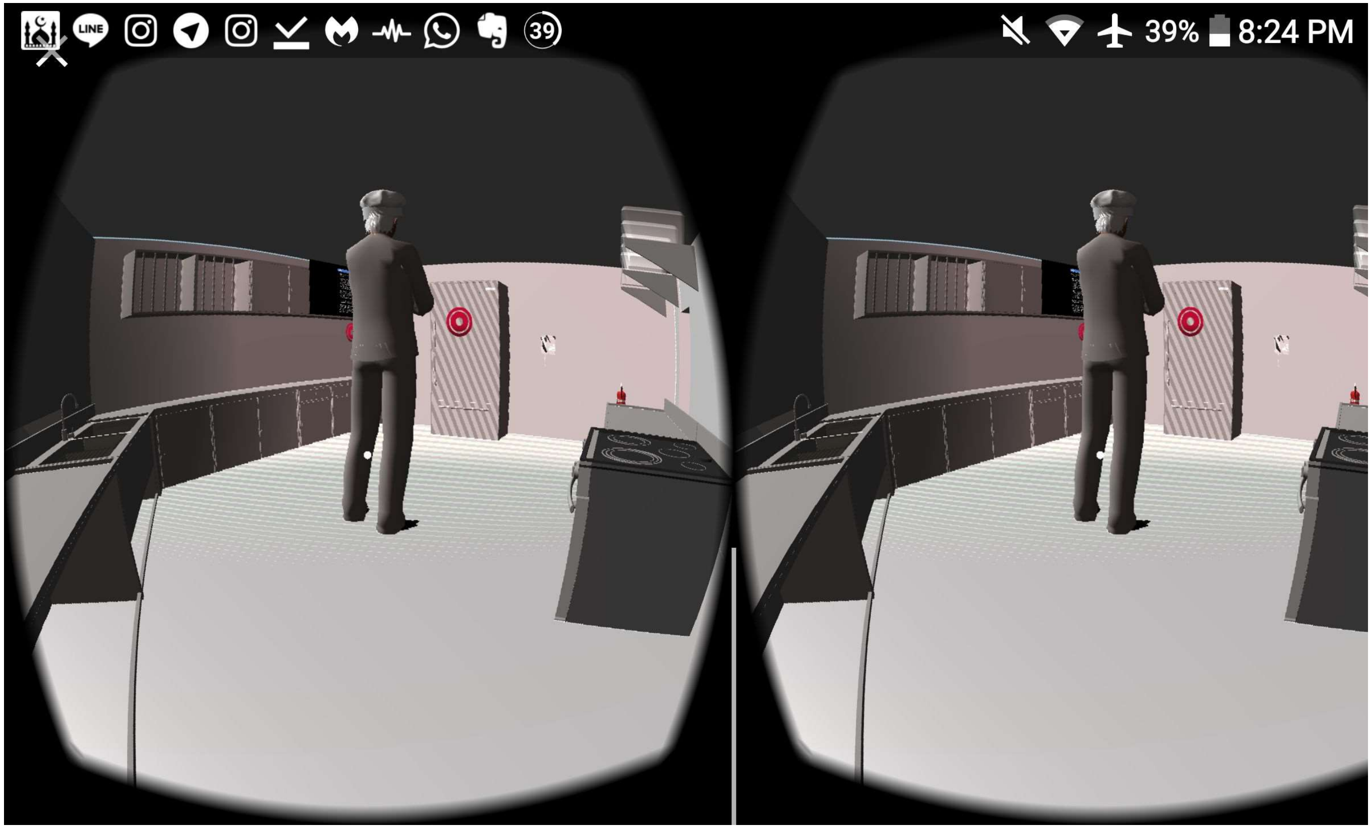

41%
8:21 PM
Inner Toilet
• If reasonable and practicable, sleeping rooms should be planned and equipped with a private bathroom, including a toilet, so as to provide reasonable comfort for the occupants and to facilitate tidiness.
Inner Toilet
• If reasonable and practicable, sleeping rooms should be planned and equipped with a private bathroom, including a toilet, so as to provide reasonable comfort for the occupants and to facilitate tidiness.


39% 8:23 PM
Washing Machine
• The laundry facilities provided for seafarers' use should include:
• (a) washing machines
• (b) drying machines or adequately heated and ventilated drying rooms
• (c) irons and ironing boards or their equivalent.
Washing Machine
• The laundry facilities provided for seafarers' use should include:
• (a) washing machines
• (b) drying machines or adequately heated and ventilated drying rooms
• (c) irons and ironing boards or their equivalent.

VIRTUAL REALITY APPLICATION



VIRTUAL REALITY APPLICATION



AUTHOR BIOGRAPHY

Born in Surabaya on August 6, 1998, Jody Muhammad Ezananda spent his formative years in his hometown, attending Sekolah Alam Insan Mulia Nature School from 2004 to 2013, then moved to Sekolah Ciputra in 2013. He graduated in 2016 and pursued Bachelor's Degree in Engineering at Marine Engineering Department of Sepuluh Nopember Institute of Technology from 2016 to 2020. During the period of his study, he gained interest in Maritime industry especially in subjects that intersect with creative/media/cultural sector. He experienced internship in PT. Industri Kapal Indonesia (2018) and PT. Nusantara Regas (2019). In his fourth year, he became a member of the Digital Marine Operation and Maintenance Laboratory, and developed a Marine Virtual Reality application for his final project. In the meantime, he was (and still is) actively involved in the local pop culture scene, writing music and journals about music, films, and pop issues.

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