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Design and research of VLCC vessel virtual marine engine room

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WORLD MARITIME UNIVERSITY

Dalian，China

DESIGN AND RASEARCH OF VLCC VESSEL VIRTUAL MARINE ENGINE ROOM

By

ZHAO CHUANG
China

A research paper submitted to the World Maritime University in partial Fulfillment of the requirements for the award of the degree of

MASTER OF SCIENCE

(MARITIME SAFETY AND ENVIRONMENTAL MANAGEMENT)

2015

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Declaration

I certify that all the material in this research paper that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this research paper reflect my own personal views, and are not necessarily endorsed by the university.

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Abstract

Title of research paper: **Design and Research of VLCC Vessel Virtual Marine Engine Room**

Degree: **Msc**

With the rapid development of computer and network communication technology, turbine simulation technology has made great progress. Different types of marine engine room simulators are invented. In recent years, the virtual reality technology is applied to Marine simulation training and it has gradually become one of the important research directions of turbine simulation system. Comparing with traditional marine engine room simulator or two-dimensional semi-physical simulation software interface simulation, 3D virtual simulation system of engine room is much better. Because 3D virtual simulation system of engine room provides the real engine working environment for users. It can provide the users with a realistic 3D visual feeling and a feel of sound and touch. As a result, it can provide a more independent and efficient training platform for users.

This paper uses VLCC marine engine room simulator of Dalian maritime university as the virtual object of the design to develop 3D virtual simulation system of engine room.

At first, this paper introduces virtual reality technology and its application in marine engine room simulator. Combine with two-dimensional marine engine room simulator design virtual simulation system to choose system development environment. Then this paper introduces the engine room scene modeling methods, processes and model specifications and makes a research of normal mapping technology in the scene optimization. It has achieved special effects of illumination model by using Unity3D built-in shader and improved the real time and rendering of virtual scene. It also makes a research about virtual scene in the engine room by using collision detection, 3D interactive picking technology. At last, this paper realized real-time data communication between two-dimensional marine engine room simulators and three-dimensional the virtual engine room simulation system by using network communication technology, so that marine engine system and equipment can be operated virtually and synchronously.

Keywords: Marine Engine Room Simulator; Sense of Reality; Shader; Interaction; three-dimensional virtual system

Contents

List of Figures

List of Abbreviations

VLCC	Very Large Crude Carrier
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
LNG	Liquefied Natural Gas
2D/3D	2 dimensional/ 3 dimensional
CPU	Central Processing Unit
GPU	Graphic Processing Unit
HLSL	High Level shading Language
OpenGL	Open Graphics Library
GLSL	OpenGL Shading Language
Cg	C for graphics
NVIDIA	NVIDIA Corporation
AABB	Axis Aligned Bounding Box
OBB	Oriented Bounding Box
PDH	Fixed Directions Hull
NetBEUI	NetBios Enhanced User Interface
TCP/IP	Transmission Control Protocol / Internet Protocol
IPX/SPX	Internetwork Packet Exchange/Sequences Packet Exchange
IBM	International Business Machine
PC	Personal Computer
LAN	Local Area Network
UDP	User Datagram Protocol

Chapter 1 Introduction

1.1 Background and significance of the research

The rapid development of world economic integration makes the shipping industry enter a stage of rapid development and it also leads to the generation of the great changes in the shipping industry of the ship at the same time. Vessels are changing towards large-scale, specialization, modernization, and these changes also mean that the complexity of the equipment will be higher and fault maintenance will be more difficult. At the same time, the requirements of governments around the world and the related institutions to protect the marine environment are becoming more and more strict, all kinds of new technology application which are beneficial to environmental protection is more and more widely applied in the ship. The 2010 STCW convention Manila amendments which came into effect on January 1st, 2012 also revised the related application of new technology. It also does a lot of corrections about the seafarers' training and competency requirements according to the changes of the current shipping environment (IMO, 2015).

These aspects require that the training crew center should have higher standards and requirements to meet the current shipping market. But the crews have little opportunities to use new equipment and the new technology. And the status of China's maritime authority established requirements to further strengthen shipping personnel training work to further strengthen, this also means that more accurate and complete marine engine room simulator developed scientific research work also must follow. But most of traditional forms of marine engine room simulator are two-dimensional simulation software interface or semi physical simulation. They are lack of dynamic display and man-machine interaction is also not friendly. As a result, people are unable to have profound understanding of structure and equipment of real engine room. While it is possible for students have a preliminary understanding of the operation of the equipment and system, but it is lack of stereo feelings. So it can't help improve the students learning enthusiasm, and it is easy to make students lose interest in learning and they cannot get further improvement from the training. These shortcomings and deficiencies are the main factors affecting the development of marine simulators. At the same time, traditional marine engine room simulator technology also has the shortcomings of long development cycle, high cost and inability to keep up with the development of new technologies. They already cannot meet the new needs of the development of shipping industry. Based on the above reasons, the major shipping agency and navigation colleges have made further improve the positive exploration about the marine engine room simulator, and virtual reality technology is one of the most important development trends of simulator studies.

In the virtual reality technology the applications can be set by some targeted features, such as scene roaming, mechanical operation, training evaluation and so on. Its powerful interactive function is used at the same time to enhance the training effect and strengthen student's understanding of mechanical equipment operation. It can also make the students who may not be on internships or work roam in the virtual engine room through the whole structure of the turbine engine room and understand the operation steps of the composition of important equipment and equipment. In the virtual engine room, we also can set some problems which we cannot always see in a real vessel, such as fire in the engine room, water entering the engine room and so on. The virtual engine room has many advantages. For example it can strengthen the ability to cope with emergencies, lower the training venues and save the cost of equipment and maintenance. It also can achieve unlimited repeated training and avoid the risks that may occur in the process of the operation of the equipment. Applying virtual reality technology to ship simulation education and developing a multi-functional, good interactivity and convenience of maintenance and upgrading virtual ship engine room simulation system have become the inevitable trends of the current marine engine room simulator development.

1.2 Research and development status of marine engine room simulator

In the early 1970s, there was very advanced marine engine room simulator technology at the time in western countries. And with the help of the development of computer technology, the marine engine room simulator was invented (Cao & Zhang, 2012). But because it could not become the ideal model, so it just could only be regarded as the primary stage. Later with the rapid development of various technologies, including computer technology, the great progress of the research of the marine engine room simulator has been made a great step. Since the 1990s, different types of marine engine room simulator have been born in succession, constantly toward large-scale and professional direction. For example, Norway's KMSS company PPT 2000 series marine engine room simulator, Germany the STN Atlas Elektronik company SES 4000 type marine engine room simulator and British Transas company ERS type marine engine room simulator. They are all the representative marine engine room simulator of this period (He & Zhang & Lin, 2007). But the marine engine room simulators of this period pay more attention to the concept and function. The benefit of the marine engine room simulators is that it brings simplification to a great extent, such as maintenance, etc. But the deficiency is that they are too abstract and difficult to understand.

Because the development of computer technology was slow in our country and our country did not pay much attention to the marine engine room simulator, the simulator research of our country started relatively late compared with western developed countries. With the rapid development of shipping industry in our country and the emergence of various maritime treaties, the major domestic research institutes and navigation colleges have accelerated the simulator research and development work. The research work of simulator in our country has reached the international level. Various types of simulators have been developed such as Dalian Maritime University: DMS series marine engine room simulator, Wuhan University of science and technology: WMS series marine engine room simulator, Shanghai Maritime University SMS series marine engine room simulator (Cao & Zhang, 2012). The characteristics of the marine engine room simulator is creating a lot of actual ship equipment simulation subsystem according to the real vessel, such as integration platform, control platform, ship power station and so on. These subsystems are installed in the laboratory. They have the advantage of practical demonstration while teaching. But there are also some disadvantages, such as covering too much space, spend too much money in earlier stage. Another point, because there are some big differences between this kind of teaching environment and the actual ship engine room environment, so it may affect education training quality. If marine equipment is upgraded, the simulator also needs to be upgraded which will costly for late maintenance. In recent years, to apply virtual reality technology to the crew training and assessment of large turbine training equipment has become one of the most important directions for the study of contemporary virtual simulation system of turbine. And the study has made certain achievements so far (Zeng &Zhang & Ren, 2014). Such as Dalian Maritime University DMS series virtual engine room management system (including container ship, LNG ships, supertankers, the controllable pitch propeller ship) and turbine virtual disassembling system. Dalian Maritime University training ship "Yukun vessel" as the mother ship has used distributed interactive simulation technology, multimedia technology, computer technology to develop virtual DMS - 2010 type marine engine room simulator system. The system has the high fidelity of the scene and good interactive operation characteristics. It is also a successful case of applying that the virtual reality technology is applied to the marine engine room simulator.

We can consider about the real vessel cabin environment when using the virtual reality technology to do the research of marine engine room simulator. We establish the virtual engine room scene by establishing the 3D model of the cabin. Users can get the similar experience with the actual ship working environment and observe the equipment layout of the ship engine room, the distribution of the pipes and the concrete structure of the main machinery and equipment via independent roaming in the virtual engine room scene. Users can master their operating methods to better understand the operation principle of the equipment via the interaction operation of the equipment in the virtual engine room scene. On the other hand, this kind of virtual cabin can be applied to any type of ship. It has big advantage when compared with the traditional turbine simulation.

Chapter 2 Virtual simulation system design of VLCC

2.1 VLCC marine engine room simulator

In this paper, taking VLCC marine engine room simulator of Dalian maritime university as the virtual object of the design to design and develop the authenticity, more immersive 3D virtual simulation system of marine simulator cabin.

2.2 Virtual simulation system design of VLCC

2.2.1 Marine engine room simulator

Marine engine room simulator uses a variety of simulation technology to design the turbine multilayer structure of the ship. The overall structure uses a variety of simulation ways and makes full use of modern network communication technology to build up high-speed Ethernet communication structure with the center of interchanger (Shen, 2013). A complete set of marine engine room simulator concludes the main power and propulsion system, main engine remote control system, fuel system, main engine condition monitoring system, compressed air system, steam system, engine room, sewage system, incinerator system, bilge water system, daily fresh water system, cleaning system, steering system, cooling system, air conditioning and refrigeration system, power system, the lubricating oil system, centralized monitoring and alarm system and fault simulation training system and so on. It covers most of systems in the engine room.

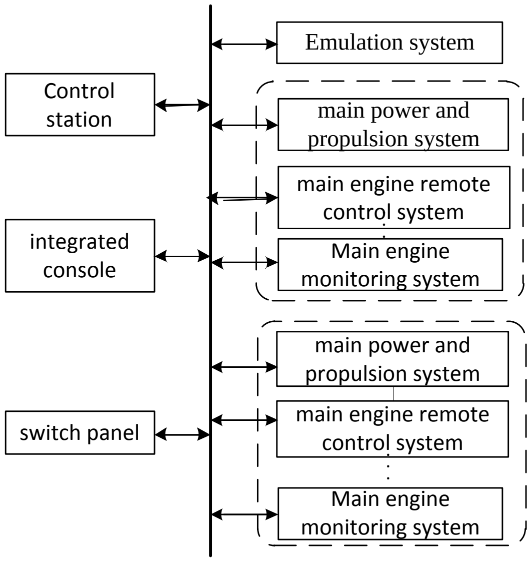

Figure.1- turbine multilayer structure of the ship

Source: the author

Marine engine room simulator two-dimensional simulation software includes all basic ship engine room system and the various systems are displayed with the form of a friendly man-machine interface. System process principle is clear. And we can master the composition of marine turbine system, functions, basic operation, troubleshooting and so on by software.

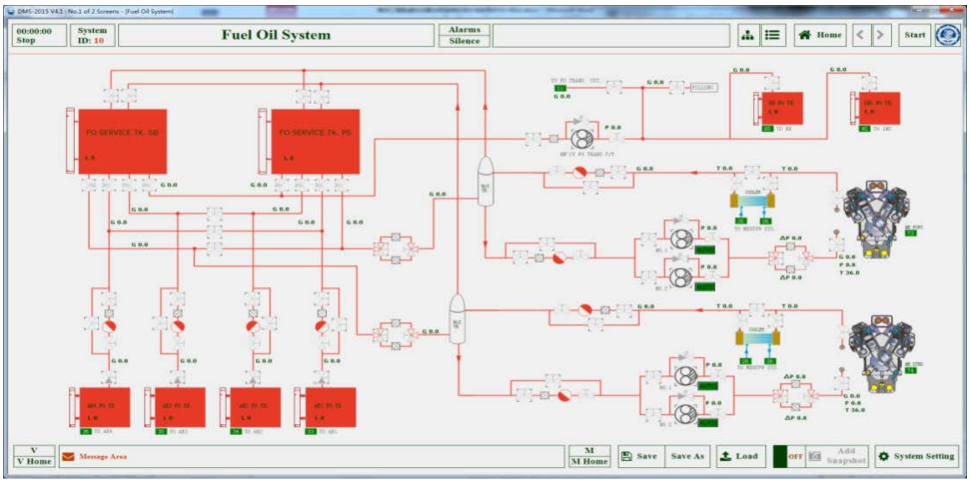

Figure.2- Fuel oil system

Source: Complied by the author using marine engine room simulator

2.2.2 Ideas for design Virtual simulation system

Because turbine machinery is always various and pipeline is always disorderly, the traditional marine engine room simulator can usually only summarize the ship engine room equipment to display in the form of principle. It cannot display the real engine room scene clearly. On the other hand, with the high-speed development of computer technology and virtual reality technology, the application in the field of Marine simulator is becoming more and more widely. Establishing a complete virtual vessel simulation system by combining the characteristics of the marine engine room simulator and application in the field of virtual reality in the turbine can provide highly realistic scene images, improve the immersive of the engine marine engine room simulator visual system and improve realism and interactivity of the engine marine engine room simulator (Sorensen, 2003). Virtual simulation system includes not only the simple roaming in engine room scene, but also the virtual operating on machinery system and equipment (such as valves, switches, etc.) with the help of simulation interaction technology in the virtual scene. And it also can realize the real-time communication and interaction between the marine engine room simulator and virtual simulation system. Virtual simulation system should also achieve the following goals：

(1) The equipment in the virtual engine room should show enough authenticity in order to make user have the strong sense of immersion. This requires that we should guarantee the authenticity of the size and shape when we establish the three-dimensional model. And we should develop proper shader to show the local details according to the characteristics of the model.
(2) Users are provided with a way to interact with the virtual scene friendly. For example, reasonable plan can be made for the camera movement to make user roam in the scene.
    Collision detection function is added to make roaming become more real and a reasonable and efficient three-dimensional pick-up algorithm can be provided.
(3) The various display instruments in the virtual engine room and movements of the actuator should comply with the law of the real vessel. So it is required to establish mathematical model with high precision.
(4) Virtual vessel should be able to provide emergency situation for the vessel, such as water come into engine room, fire in the engine room and so on which is hard to meet in the real vessel.

2.2.3 Frame structure of virtual simulation system

Operators control the interaction entity (such as valve of system equipment, button) in 3D virtual cabin entity through interactive devices (such as keyboard, mouse) to interact with virtual cabin. Operation instructions are sent to the two-dimensional simulation module to do the simulation calculation through the network communication module. The result of the system status will be sent back to 3D virtual engine room scene, and the result will turn into the real-time interactive display through the interaction entities (such as indicator, etc.) of 3D engine room scene.

At the same time, the operator can also control two-dimensional simulation module to interact through interactive devices, and also can achieve the same effect through physical disk operation (Huang, 2009).

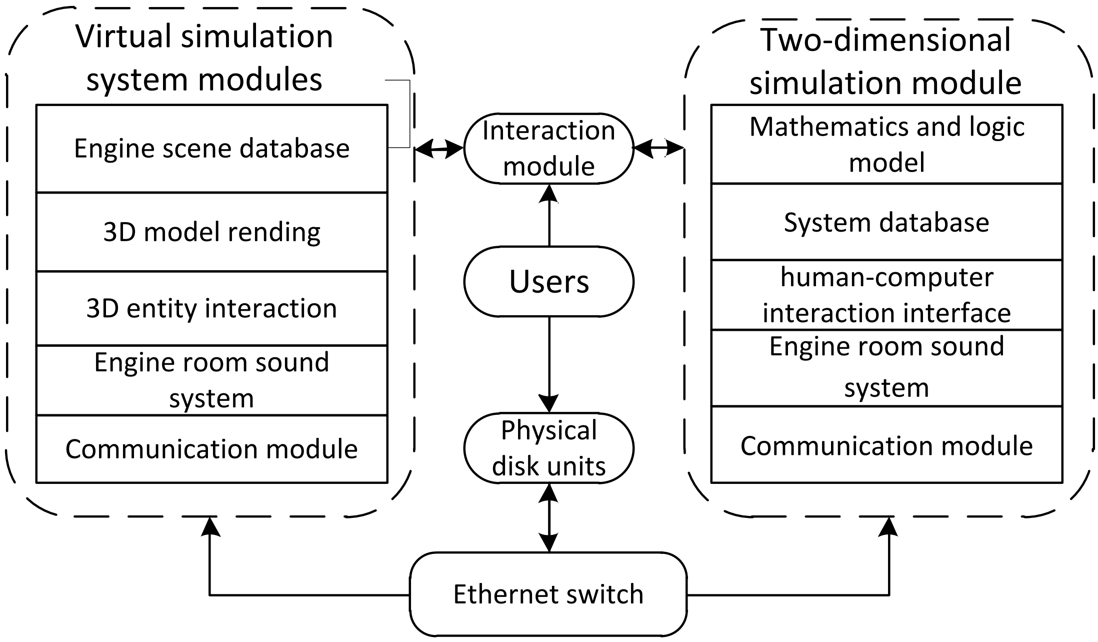

Figure.3- virtual simulation system framework

Source: the author

System mainly includes the virtual simulation system module, the 2D simulator simulation module, physical disk, interactive devices, Ethernet switches, audio equipment and so on (Zhang, 2014).

(1) The virtual simulation system modules

1. Engine room 3 d scene database. It is used to save the scene system of 3 d model, texture material and the interaction scripts, etc.
2. The 3D rendering graphics. In this paper, it is to use Unity 3D shader to color the three-dimensional objects, the calculation of light and shade, texture and color rendering and so on to achieve the real effect of 3D virtual scene.
3. 3D entity interaction, it is mainly for the user and the 3D interactive entities to interact in the scene, including in the virtual scene roaming, collision detection and 3 d pick up functions, etc.
4. Communication module. It is used to achieve the data exchange and sharing between 3D virtual scene and two-dimensional marine engine room simulator and physical disk.

(2) The two-dimensional simulation module

1. Mathematics and logic model base. The mathematical model of marine engine room simulator system equipment is stored in a two-dimensional simulator simulation module. The state is updated in real time by using mathematical and logical model libraries system.
2. The system database. It is used for real-time simulation data of the storage system.
3. The human-computer interaction interface. It is used to display system equipment and piping in the engine room with the principle diagram of system equipment. Users control the system equipment such as valve parts, buttons and knobs through the interface.
4. Engine room sound system. It is used to simulate equipment start-stop sound, vessel alarm sound, the sound of switch and button.
5. Communication module. It is used to achieve exchange and sharing between 3D virtual scene and two-dimensional marine engine room simulator and physical disk data.

(3) Interaction module, the physical disk

1. Interaction module, mouse, keyboard and other input and output devices, user can control the system interaction points of the 2D simulation module and the 3D virtual simulation system module through the interactive module and roam in the 3 d virtual scene.
2. Physical disk. It mainly includes distribution board controller, control units.

2.2.4 Development environment of virtual simulation system

The development tools in this paper include MATLAB, Microsoft Visual Studio 2013, CorelDRAW X6, 3ds Max, Unity3D software and so on. MATLAB is mainly used to establish the mathematical model and simulation in ship system to ensure that the system simulation result is consistent with the real ship. Microsoft Visual Studio 2013 is mainly used in the writing of the two-dimensional simulation software simulator, using c # language to make code for the ship model which has been built and making the human-computer interaction interface to ensure the final show state of the system (Shen, 2013).

CorelDRAW X6 is mainly used for graphics image display of the bottom of the equipment of human-computer interaction interface. 3ds Max is mainly used for making the model of machinery equipment and piping model in 3 d virtual engine room scene. Unity3D is mainly used for the implementation of 3D pick up and action show of interactive entity in the 3D virtual cabin scene.

2.3 Conclusion

This chapter mainly introduces and summarizes VLCC virtual simulation system, virtual simulation system design idea, design of frame structure and the development environment which is involved in the development process and so on.

Chapter 3 Engine room scene modeling

Whether virtual environment is realistic and can enable users to generate immersive depends on the person's subjective feelings for the environment. The Visual effect of virtual environment is one of the key factors affecting the user immersive, because about 80% of people's perception of information is obtained through visual channels (Li, 2014). Three-dimensional model is the basis for virtual environment, the effect of realistic roaming in three-dimensional scene is directly related to the precision of the model. In order to better roaming, it needs to construct a high-precision model, but it will increase the workload, and more importantly, it will seriously affect the real-time roaming. Therefore, in the process of modeling we need to compromise in terms of model accuracy and speed of drawing which not only guarantees the better model quality, but also ensures that the construction speed. Many of the three-dimensional model are covered by textures, and the process in which texture is arranged on the three-dimensional model is referred to as "texture mapping”. Texture is an image, but it can make model more meticulous and looks more real.

In addition to texture, some other effects can also be used to model to increase the sense of reality. For example, it can adjust the normal of curved surface to achieve the light effect, and some can use the concave and convex surface texture mapping method and some other 3D rendering techniques to make it more realistic (Watt, 2000).

3.1 The selection of modeling software

With the development of computer technology, nowadays many softwares are used to construct three-dimensional models, such as 3ds Max，Maya，Solidworks，Pro/e, and so on. The softwares are not only powerful, but each has their merits and advantages.Pro/e and Solidworks is mainly used in the field of engineering machinery due to its high-precision in modeling. Relatively speaking, the operation of Maya and 3ds Max is very simple and easy to use in modeling, and they have the great advantages in the model optimization, rendering, and animation and visual effects (Zhang, 2008). In this article, the internal structure of ship cabin which equipped with many equipment and pipes is very complex, and does not need to be very accurate in size, but the scene would to be very realistic. Therefore, this system appropriaty chooses 3ds Max or Maya as a scene modeling tool. According to the personal preferences, I choose 3ds Max software.

3ds Max is one of the world's biggest-selling of three-dimensional production softwares. Its function is very powerful and it has extensive applications. 3ds Max has high stability and good compatible effect, and it can support a variety of plug-ins, such as in the rendering. In addition to its own renderer, it also supports a variety of plug-in renderer in order to achieve a more realistic rendering. There are a lot of modeling ways of 3ds Max, We can choose the best modeling method based on the characteristics of the object. The common way of modeling includes basic physical modeling, editing modeling, dimensional graphical modeling, composite object modeling, mesh modeling, polygon modeling, patch modeling and MURS modeling, and so on (Zhang, 2008). We can create any modeling that exist in the real world, and can also design and create any virtual scene. 3ds Max provides platform for designers that can show their design concept and demonstrate the practical application. The design concept can be showed by three-dimensional model, and it makes people understand the scene more directly.

3.2 Setting up engine room scene

All of the digital models mentioned in this paper are made by 3ds Max, and even as for the different driving engines, the requirements of the model is basically the same. When a VR model is completed, it contains the basic content, including the size of scene, unit, naming, node editor, texture, coordinates, grain size, texture format, material of the ball and so on. They must be in conformity with the production specification. As for the process control management, a clear classification and production specifications model file is very necessary.

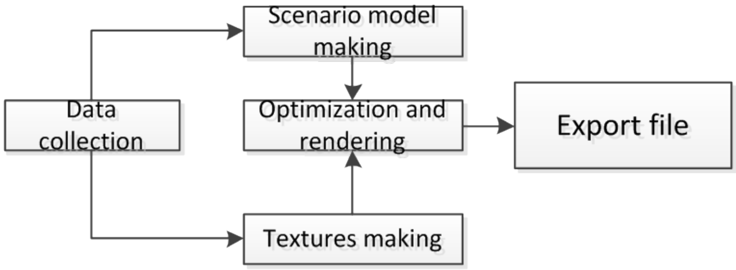

Figure.4- Modeling process of virtual scene

Source: the author

3.2.1 Data preparation

Data preparation is an important and complicated work, which will be established in relation to the accuracy of the model appearance and relative size. The main task of this phase is the wake collecting and processing of the data of Marine engineering ship in preparation for the geometric modeling and the follow-up work:

(1) Basic data: In the process of shipbuilding, shipyards and large equipment manufacturer will provide ship design and equipment information. All of the drawings are in CAD format, or a WORD and PDF format which is of help for modeling. In CAD drawings, there are the principle diagram of the system, the cabin layout, equipment size and installation drawing and so on. At the time of need, We will simply handle these drawings, delete the construction and attribute information during the modeling, Then, the simplified section with size information will be saved as DWG format, and imported into 3ds Max used in modeling. On this account, We can ensure that the cabin size and relative position are consistent with the actual position (Kniss, 2003).

(2) Data collection: this system is virtual scene based on the real engine room environment model, In addition to the testing result data, we must obtain the real cabin institutions, equipment, piping layout and other data by taking photos, video

and other means. In addition, all sorts of identification, equipment nameplate of the engine room and so on also are obtained by taking photos. Some pictures can also be used to make the map to add realism to the scene (Zeng, 2012).

3.2.2 Scene making and specification

3.2.2.1 Scene making and specification

3D modeling is time-consuming, but it is also the basis and premise of 3 d virtual scene. The precision of 3D model is directly related to realism of the scene, but the model is not as detailed as possible, because it will further increase the amount of work. When modeling, what is more important is that the file, which is too large, will seriously influence the operation of the system speed, and reduce the real-time of navigation.

There are totally twenty-four engine cabins in this system, some of which contain a large quantity of equipment and piping. The equipment contains a lot of spare parts, which is a very complex large-scale scene. As for the large-scale scene, we can use a structure based on a tree network to describe the hierarchical structure of the scene. When building the model, the modeling organized step-by-step can save a lot of time and energy.

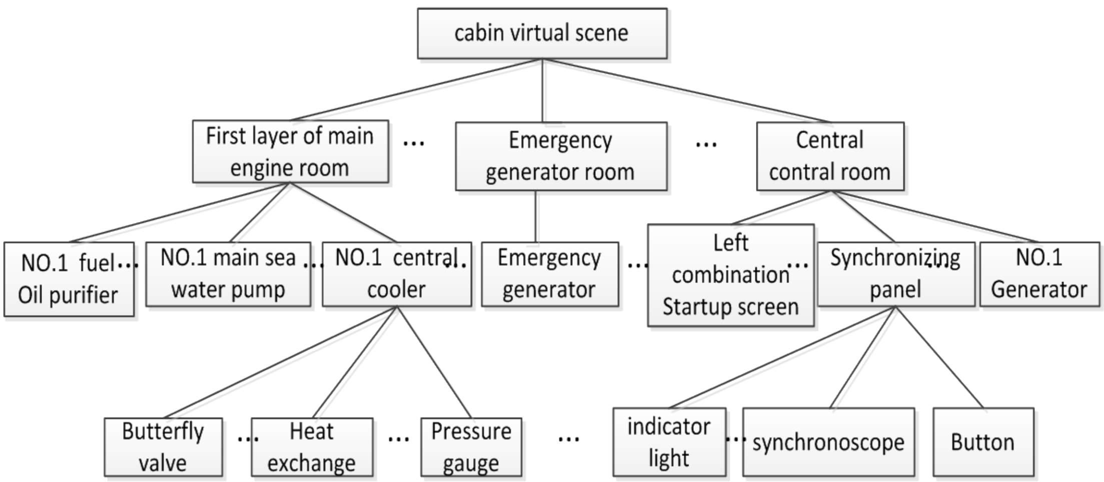

Figure.5- the hierarchical structure of the virtual scene of the cabin

Source: the author

When building the model, although there are a lot of equipment and components, most of them can be divided into different classes, such as motor, pump, buttons, lights, table, valve and so on. In the same class, such as valve, it can be divided into ball valve, globe valve, butterfly valve, gate valve and so on. As for the same kind of parts, as long as we make a scene, then, others can directly copy it to use (Zeng, 2012). The detailed modeling process would not be explained here.

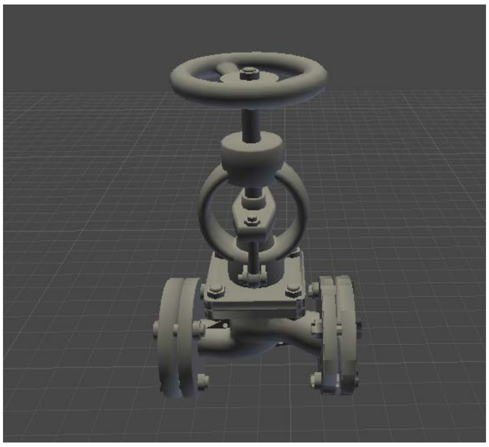

Figure.6-3D model of a kind of stop check valve

Source: Complied by the author using 3ds Max

In order to optimize the model and coordinate the relationship between the model precision and speed, the following are some of the production specifications in the aspect of modeling in this paper:

(1) Before the division of the work making model, model location criteria must be determined. The criteria usually are a CAD base map. Producers must determine the location of the model in accordance with the files which shall not be modification. The CAD base map was guided into 3ds Max and located in the point (0, 0, 0) in order to help producers make model in the position of zero.

(2) Remove excess surfaces in the scene. When making the model, the model out of sight cannot be made, and invisible surfaces can also be removed, which mainly aims to improve the utilization of chartlet, reduce number of surfaces of the whole scene, and improve running speed of the interaction scenarios, for example bottom surface of BOX.

(3) Boolean operators will greatly increase the number of model surfaces in modeling process, which seriously affect the computer running speed, so it is necessary to minimize the use of boolean operators at the actual modeling. For grids in the cabin, we can perform using textures with alpha channel and avoid tooth and flicker in the running time.

(4) Keep the distance between the surfaces of the models and recommended minimum spacing at about 1/2000 of the largest scale in the current scene. If the distance is so little, like grids in (3), there will be Z-buffer contention, then the result is that two faces flicker begin alternately appears. Never allow coplanar surface, leakage surface and reverse surface between the models. So In initial modeling stage above-mentioned facts must be checked.

(5) Copy if possible. If one object with 1000 surfaces is copied to one hundred same objects, they consumes about the same resources with one object.

(6) Make best use of Editable Poly surfaces, and this modeling approach can avoid the phenomenon of triangle surfaces.

(7) It is better not to use Chinese to name model, it is better to use English name. Standard naming can not only avoid the repetition of model and texture names, but also reduce work of late debugging optimization.

3.2.2.2 Texture making and specification

Materials and textures are the editing systems with powerful function and complex construction in 3ds Max. It is used to simulate the texture, lighting, color and other characteristics of real materials. In the actual model production process, pure material (without texture) cannot meet the requirements of the scenarios in most cases, so models will be added some texture. Before the models add texture, you should create a new material with the same or corresponding name with the texture, then add texture to the material, at last add material to the appropriate model and the texture will perform in model surface. If the texture is supposed to show the effect of the material surface, the material is the carrier of texture and records texture information (Dou, 2010).

(1) Material

Material, simply means the texture of the object, in the three-dimensional world, which shows texture, color, refraction light, reflected light and the various surface properties of all meshes after rendering. It is also a simulation of the visual effect of real material.

In 3ds Max, there are 15 material types, including standard material being as default material. Standard material substantially applies to all of simulation systems and is often used in modeling. It should be noted that, standard material must be used in the sub-materials of before and after of the model collapsed multi/sub-object material, or not being supported by unity3D.

(2) Texture

Texture is the properties applied to the material, and it is more real than the basic material. The use of texture can give the model surface the specific texture and pattern, and can be a good show about detailed brightness changes in a simple model, and can achieve light refraction and reflection, etc. So make three-dimensional scene become more real, more immersive.

Most texture in the system is made by CorelDraw or Photoshop, in accordance with a real ship, and there is some texture we can get from the photographs taken by "digging" form. On texture formats, the texture without tunnel uses JPG format and the texture with tunnel uses 32 TGA format; texture size must be 2^n, and this system should not exceed (1024 × 1024). In addition the texture is also stored as TGA format.

Figure.7- Textures of current meter dial（left）and checkered plate（right）

Source: Complied by the author using Photoshop

(3) Material editor and UVW Map modifier

Materials and textures edited mainly done in the Material Editor, and "UVW Map" modifier control how to display the object's surface textures and program material and control how to turn the bitmap onto the object.

(4) Maps and materials application rules

1. The name of the material ball must be consistent with the object name;
2. The parent-child hierarchy name of the material ball must be consistent;
3. The ID number of Material ball must be consistent with the object ID number;
4. The map cannot be named in Chinese, and the different map cannot have the same name;
5. The same kind of maps must use the same material ball;
6. The objects cannot use double sided materials except those which must use double sided materials for performance;
7. The map with Alpha channel must add _al in naming to distinguish.

3.2.2.3 Scene render, bake and export

In order to create a realistic three-dimensional scene, the baking of the model is an essential step. It is to render a map with the original texture of the object, light information and shadow effects of the object. And perform the effect of light and shade on the surface of the model by loading the baking map when the scene is in real-time rendering. This is a kind of static effect of the light shadow. When the computer re-loading the baking map, do not need to do lighting calculations again, and it can reduce the amount of computation, but the baking map resources will occupy a larger memory space.

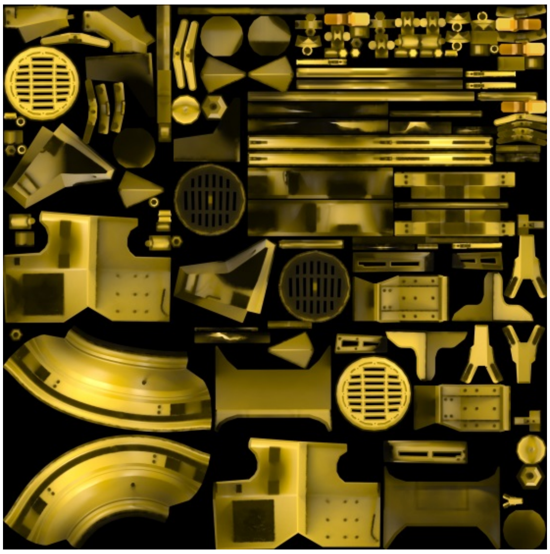

Fig.8- Render to texture of diesel generator

Source: Complied by the author using 3ds Max

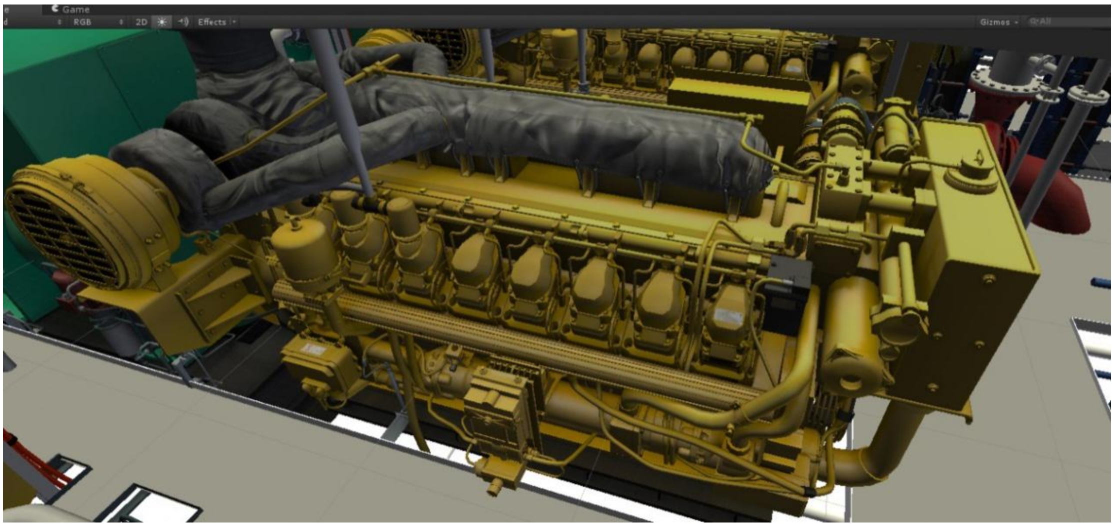

Fig.9- Render effect of diesel generator

Source: Complied by the author using 3ds Max

In 3ds Max there are two kinds of the baking way. One is LightMap baking way and the baking maps rendered by this way just have the shading information only, including the basic texture. Specifically used in the production of model files whose texture is clearer, the principle is get the basic texture map of the model and the LightMap shadow map overlayed. The advantage is the texture of the ultimate model will be clearer, and you can use the texture map repeatedly, so the texture resources can be saved; the models after baking can export the FBX file directly without the map channel modified. The disadvantage is the map in LightingMap way without the high light information. The other one is CompleteMap baking way. The advantage of this baked map approach is the rendered map itself has the basic texture and lighting information, but the disadvantage is that it has no detail texture, and the texture is vague when you are close to it. But this article does not use these two methods. It uses the V-Ray renderer for rendering. V-Ray renderer is the mainstream renderer of 3ds Max with powerful function, stable operation, fast speed and realistic rendering. It not only fully supports light, material and shadow of 3ds Max, but also comes with the V-Ray unique light, texture, shadow and hair effect. The use of these material and shadow cooperating with the V-Ray renderer will get the faster and better rendering result (Badt, 1988).

Finally, we should check same name problem of the model, merge the vertices and remove the useless objects outside the scene. Then export the scene as .FBX format in order to use in Unity.

The following pictures are 3D model scene of the air compressor room and engine control room after rendering.

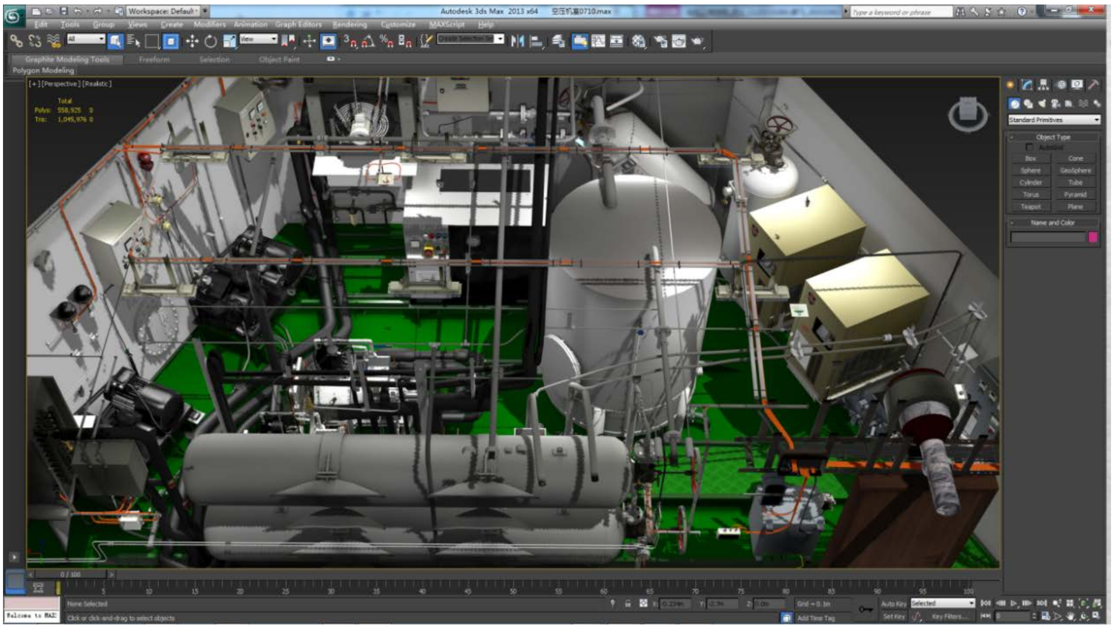

Figure. 10-D model of compressor room

Source: Complied by the author using 3ds Max

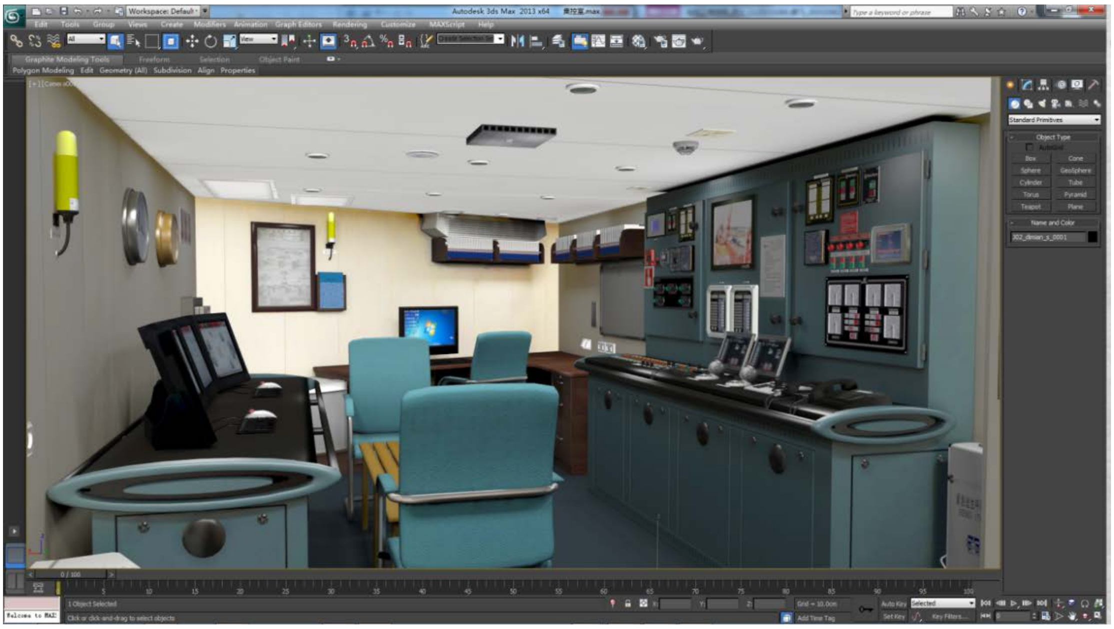

Figure.11- 3D model of engine control room

Source: Complied by the author using 3ds Max

3.3 Normal mapping technology

In the large-scale scene as engine room, there must be many structures or equipment whose surface is bump, or uneven. If we increase the number of the model grids to show the irregularities case when modeling, of course, we can get a good result. But the high surface number will increase the amount of calculation of computer, increase the demand for internal memory, and cause the scene loading slowly and stopping phenomenon.

So we can use the map with bump texture to achieve the bump effect. But the method which we use map partial shading change to achieve 3D effect is not very good. If the perspective changed, it looks no difference with a flat pattern with simple picture. Because recording the true bump case does more harm than good, and the simple bump texture effect cannot reach the desired result, the normal map may be a good choice (Kilgard, 2000) .

3.4 Conclusion

This chapter mainly introduces the process of establishing three-dimensional model of engine room scene. It also summarizes some modeling and further introduces the texture mapping technology in this paper.

Chapter 4 The implementation of three-dimensional virtual system

4.1 The implementation of the Unity 3D engine shader

Whether the virtual environment is realistic and enables users to feel immersive depends on the subjective feeling of people to the environment. The factors that influence the human senses include fine degree of three-dimensional model and more importantly includes the material and shader model design. In this section the paper designs and achieves a reasonable and realistic shader by using the latest features of the Unity3D image processing. And this paper also achieves illumination model based on Lambert, Phong, Blinn–Phong improving the real-time and realistic feeling of visual system of marine engine room.

4.1.1 Introduction of shader

The shader is a program running on the CPU, used for three-dimensional objects shading, light and shadow calculations, texture color rendering and so on. The shader can make that the model, scenes and special effects are similar with the real world. Because of shader effects, we can see, feel, and even immersed in the virtual world computer technology has created (Unity, 2012).

Along with upgrading hardware performance of GPU, shader programming way has experienced from the initial fixed line to the development of the programmable pipeline. Shader has two basic types vertex shader and fragment shader. Vertex shader has a function that can handle, convert and eventually render to the screen mesh vertex positions, but it can’t generate new vertices. Vertex shader output will be passed to the next step in the pipeline. After hardware rasterize geometry of the grid, in the fragment shader assembly line will be executed. The fragment shader will do a lot of tests on one fragment such as Z depth test and the Alpha test. The fragments which pass all kinds of test will eventually be written to the output of the render, and thus become a visible pixel on the screen of the display.

Shader is as a program running on a GPU. But it is completely different with the program running on the CPU. But the GPU is known as GPU, not another CPU in multi-core CPU. Because they are completely different in nature with CPU, the difference in nature is reflected in the hardware design of the structure, resulting in its differences from the CPU processing power. Reflected in the written program, GPU requires a completely different programming language. At present there are three kinds of GPU-oriented programming advanced image Language to choose from: Microsoft provides HLSL (High Level shading Language) that is written by Direct3D graphics library shader program Language; OpenGL provides us with GLSL (OpenGL shading Language) to write shader program; Cg (C for graphics) language developed by NVIDIA. The intention of the NVIDIA development Cg is to put graphics application development independent of Direc Ⅸ and openGL graphics library (Kilgard,2000) .

4.1.2 The application and implementation of virtual engine room shader

Unity3D is known as the best cross-platform game development engine, using Mono open source. Unity3D is known as the best cross-platform game development engine, using NBT of Mono this open source to achieve. To adapt to different shader GPU, use a custom shaderLab Unity to organize the content of the shader, and will focus on different platforms to compile.

In the structure of the Unity of shaderLab provided, we can both use GLSL to write shader logic code and use Cg / HLSL to write. If using GLSL, the code must be located between GLSLPROGRAM and ENDGLSL keywords; if using Cg / HLSL, the code must be located between CGPROGRAM and ENDCG. Cg programming language is used in this paper. The language and the C language are very similar, as a shader programming language, which offers a new library. Unity3D comes with over 60 shaders. These Shaders are divided into five categories: Normal Shader Family, Transparent Shader Family, Transparent Cutout Shader Family, Self-llluminated Shader Family, Reflective Shader Family. This picture show some applications of virtual engine room shader (Unity,2012).

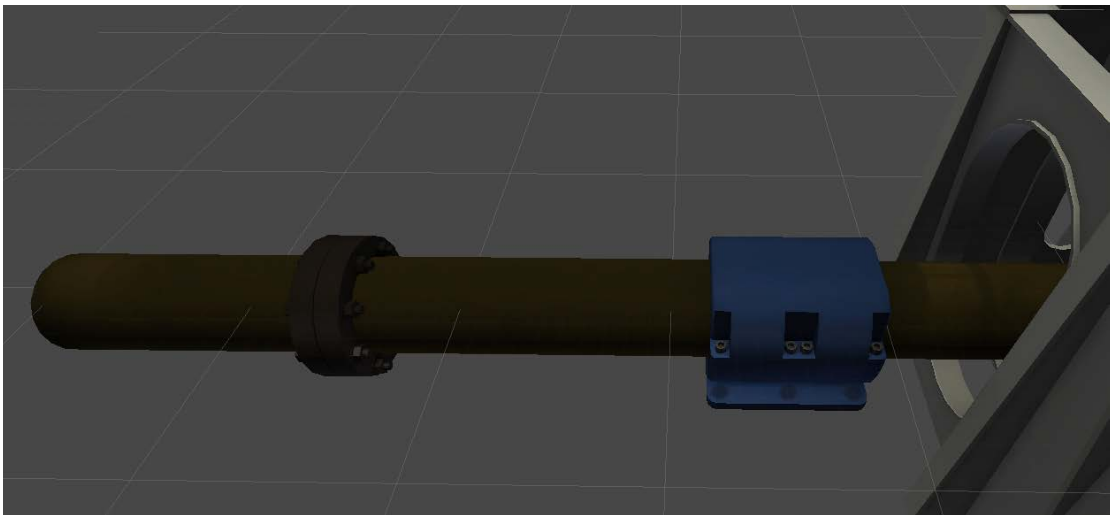

Figure.12- Effect picture of shaft with default shader

Source: Complied by the author using Unity

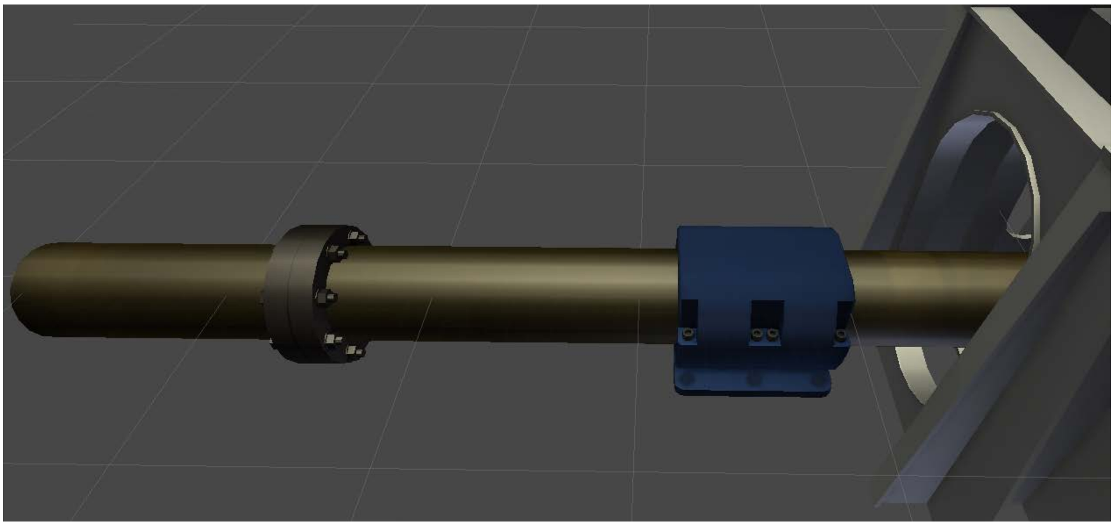

Figure.13- Effect picture of shaft with Specular shader

Source: Complied by the author using Unity

Figure.14- Comparison of effect picture of fire extinguisher with different shader

Source: Complied by the author using Unity

4.1.3 Lighting model

Lighting effects are important factors affecting realistic scenes. Usually fixed rendering pipeline used the standard local illumination model, the model is usually integrated in OpenGL and Direct3D standard graphic interface. Ship engine room has a more complex indoor scene. In order to meet operational need engine room contains a variety of complex lighting. They are different from daily indoor and outdoor scenes. Therefore, in order to achieve more flexible lighting effects, we must extend and improve the standard of illumination model. The following are some lighting model.

4.1.3.1 Diffuse reflection and Lambert illumination model

Rough surface has the same intensity reflected light in all directions. This phenomenon is known as the diffuse reflection. The surface which produces the phenomenon of diffuse reflection is called ideal diffuse reflection light. It is also known as Lambert reflector. Even if an ideal diffuse reflector has same amount of reflected light in all directions, but surface light is still rely on light incident direction (the direction of light). Lambert lighting model of vector diagram as shown in figure:

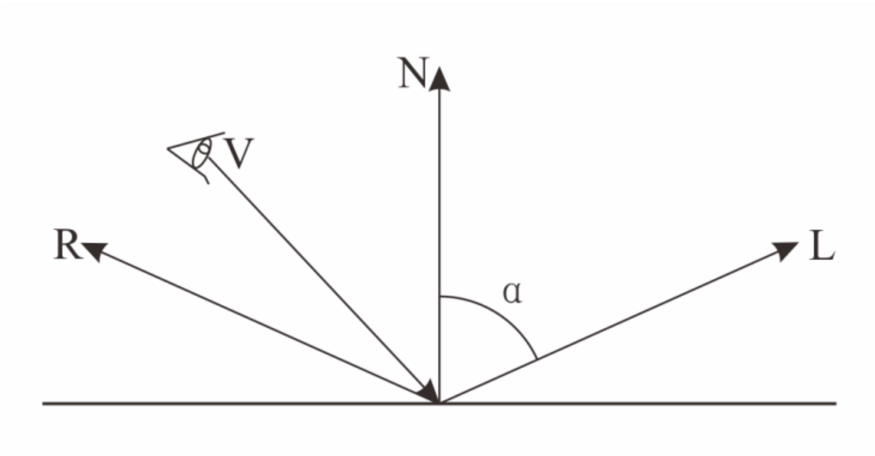

Figure.15- vector express chart of Lambert lighting model

Source: the author

Where N is normal vector of vertex; L is the direction of incident light; R is the reflection of incident light; V is observation vector from observation position to observation point. And Lambert diffuse model is constructed.

$$I_{diff}=k_d*I_l*\cos\alpha \quad (4\text{- }1)$$

Where I_l is intensity of pointolite; θ is included angle between the direction of incident light and vertex normal called incident angle (0≤α≤90°), I_{diff} is light intensity reflected by diffuse reflector interacting with directional light; When the value of incident angle is zero, the light is perpendicular to the object surface and the light intensity of diffuse reflection is the largest; when incident light is parallel to the object surface that the value of incident angle is 90, it means the object doesn't receive any light. If N is vertex unit normal vector, L is unit vector from vertex to light source, so it is equivalent to the dot product of N and L. so formula (4-1) can be expressed as formula (4-2):

$$I_{diff}=k_d*I_l*(N\cdot L) \quad (4\text{- }2)$$

The key code is as follows：

```
//Lambert illumination model
inline fixed4 LightingLambert(SurfaceOutput s, fixed3 lightDir, fixed atten)
{
    // Calculating the consine value of included angle between the direction of incident light and vertex normal
    fixed diff = max(0, dot(s.Normal, lightDir));
    // Defining returned data structure of color
    fixed4 c;
    // Caculating the final color data
    c.rgb = s.Albedo * _LightColor0.rgb * (diff * atten * 2);
    c.a = s.Alpha;
    // returning the final data
    return c;
}
```

4.1.3.2 Specular reflection and Phong illumination model

Lambert model shows the phenomenon of light on the rough surface very well, such as whitewashed walls, paper, etc. But when Lambert model is used for objects made of metal material, the effect is stiff and there’s no luster. The main reason is that Lambert model does not consider the effect of specular of these surfaces. Every smooth object is exposed to light, we can see strong reflected light in a certain direction. It is because the object reflects all or most light intensity in the region near the specular reflection angle. The phenomenon is called specular reflection (Chen & Zhou, 2002).

Therefore, Phong Bui Tuong put forward an empirical model to calculate light intensity of specular reflection called Phong illumination model. He thinks that the light intensity of specular reflection is associated with the angle between reflection light and the line of sight, the vector representation of Blinn-Phong.

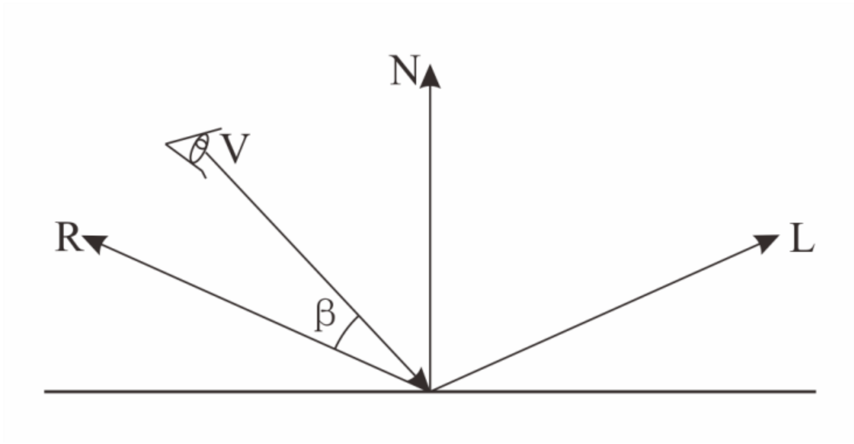

Figure.16- Ector express chart of Phong lighting model

Source: the author

The mathematical expression, as shown in formula (4-3):

$$I_{spec}=k_s I_l (V\bullet R)^{n_s} \qquad (4\text{- }3)$$

Where k_s is specular reflection coefficient of material, n_s is specular index, β is included angle between observation vector and reflection vector. Specular index reflects the gloss of object surface. The bigger n_s is, the more concentrated the reflected is. When deviating from the direction of reflection, the light attenuates severely，Specular phenomenon can be seen only when line of sight direction is very close to the direction of reflected light. At this point, the specular reflection light will form a bright and small speckle near the reflected direction. The smaller n_s is, the more rough the object is and the reflected light is more dispersal, so the speckle observed is small and weak (Chen & Zhou, 2002).

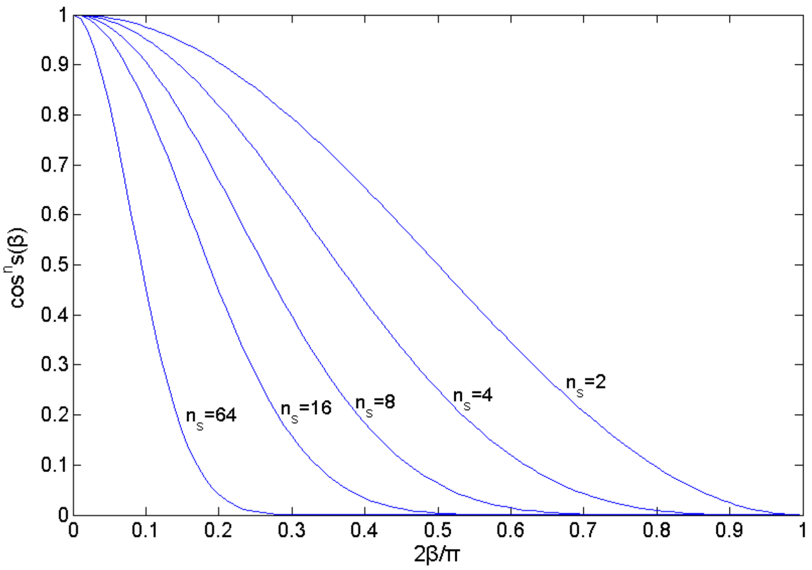

Figure.17- Cular reflection power of Phong illumination model

Source；the author

The direction of reflected light *R* can be determined by the direction of incident light and the normal vector of the object *N*:

$$R = (2N\cdot L)N - L \qquad (4\text{- }4)$$

So formula 4-4 can be written as:

$$I_{phong}=I_{diff}+I_{spec}=k_d*I_l*(N\cdot L)+k_sI_l(V\cdot((2N \cdot L)N - L))^{n_s} \qquad (4\text{- }4)$$

The key code is as follows:

```
inline fixed4 LightingPhong(SurfaceOutput s, fixed3 lightDir, half3 viewDir, fixed atten)
{
    // Calculating the cosine value of included angle between the direction of incident light and vertex normal
    fixed diff = max(0, dot(s.Normal, lightDir));
    // Calculating the reflected light vector
    fixed3 reflection = normalize(2.0 * s.Normal * diff - lightDir);
```

```
    // Calculating Phong specular reflction
    fixed spec = pow(max(0,dot(reflection,viewDir)),_SpecPower) * _SpecularColor.rgb;
    // Defining and returning the result
    fixed4 c;
    c.rgb = s.Albedo * _LightColor0.rgb * diff + _LightColor0.rgb * spec * atten * 2;
    c.a = s.Alpha;
    return c;
}
```

4.1.3.3 Blinn-Phong illumination model

Blinn-Phong illumination model, also known as Blinn–Phong reflection model or modified Phong reflection model, is modified by Jim Blinn in 1977 on the base of traditional Phong illumination model. Compared with traditional Phong illumination model, Blinn-Phong illumination model combines the diffuse part of Lambert illumination and standard highlight, the render effect is more soft and smooth than Phong illumination model, furthermore its render speed is pretty fast, so it is the default illumination rendering method in many CG softwares. In addition, Blinn-Phong illumination model is integrated in most Graphic Processing Units to generate fast rendering (Blinn, 1977). In OpenGL and Direct3D rendering pipeline，Blinn-Phong illumination model is the default rendering model.

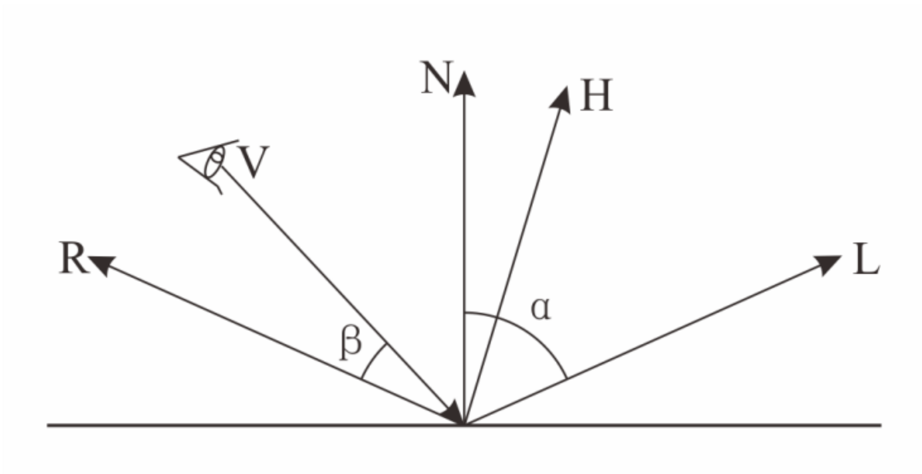

Figure.18-Ector express chart of Blinn-Phong lighting model

Source：the author

Jim Blinn improved Phong illumination model and introduced semiangle vector H. H is a halfway vector between light incident direction vector L and viewpoint direction vector V, and usually called as semiangle vector. Its expression is that:

$$H=\frac{L+V}{|L+V|} \tag{4- 5}$$

Blinn-Phong illumination model formula can be amended as:

$$I_{spec}=k_s I_l (N \cdot H)^{n_s} \tag{4- 6}$$

Then Blinn-Phong illumination model formula can be amended as:

$$I_{Binn\text{-}phong}=I_{diff}+I_{spec}=k_d * I_l * (N \cdot L)+k_s I_l (N \cdot H)^{n_s} \tag{4- 7}$$

In general, render effect of using Blinn-Phong illumination model and Phong illumination model don’t have much difference, but the running speed of Blinn-Phong illumination model is faster because of omitting two multiplications for calculating the direction vector of reflected light ray. Here is shader code of Blinn-Phong illumination model:

```
inline fixed4 LightingBlinnPhong(SurfaceOutput s, fixed3 lightDir, half3 viewDir, fixed atten)
{
    // Calculating the cosine value of included angle between the direction of incident light and normal direction
    fixed diff = max(0, dot(s.Normal, lightDir));
    // Calculating semiangle vector
    float3 halfVector = normalize(lightDir + viewDir);
    // Calculating Phong specular reflection
    fixed spec = pow(max(0, dot(halfVector, s.Normal)), _SpecPower) * _SpecularColor * _SpecularColor.rgb;
```

```
    // Defining and returning the result
    fixed4 c;
    c.rgb = s.Albedo * _LightColor0.rgb * diff + _LightColor0.rgb * spec * atten * 2;
    c.a = s.Alpha;
    return c;
}
```

4.1.3.4 light attenuation model

Although Blinn-Phong illumination model is relatively real, it doesn't consider attenuation of the transmission of light with distance becoming larger, and it can lead to the same illumination intensity of objects near and far in scene and which has a strong impact on the reality of scene (Blinn, 1977).

In order to solve this problem, attenuation coefficient is introduced to simulate the attenuation effect of light. The attenuation coefficient is calculated by using a quadratic polynomial of *d*, and it is inversely proportional to the distance of light source to the point of irradiation, as is shown in formula (4-9):

$$K_a=1/(k_1 d^2+k_2 d+k_3) \quad (4\text{- }8)$$

k_1、k_2、k_3 are quadratic attenuation coefficient, linear attenuation coefficient, constant attenuation coefficient. So Blinn-Phong illumination model of a single light source can be amended as:

$$I_{Binn\text{-}phong}=K_a(I_{diff}+I_{spec})=K_a(k_d*I_l*(N\cdot L)+k_s I_l (N\cdot H)^{n_s} \quad (4\text{- }9)$$

The key code is as follows:

```
float k1=0.1; // quadratic attenuation coefficient
float k2=0.1; // linear attenuation coefficient
float k3=1; // constant attenuation coefficient
// Calculating attenuation coefficient according to position vector of point light source
```

float K_a =1/（k_2*pow(length(lightDir),2)+ k_1*length(lightDir)+ k_3）;

// Applying attenuation coefficient to the final illumination model

c.rgb =K_a*(s.Albedo * _LightColor0.rgb * diff + _LightColor0.rgb * spec * atten* 2);

c.a = s.Alpha;

return c;

4.1.4 Light rendering

From left to right, which in turn is the effect of a valve of virtual engine room using illumination model of Lambert, Phong, Blinn-Phong:

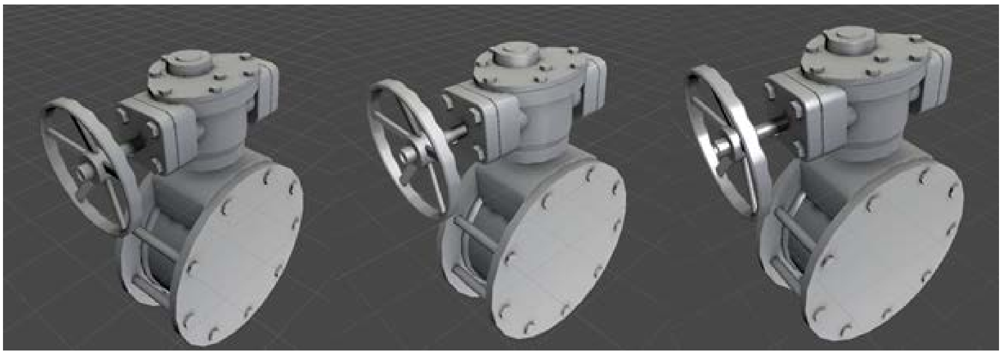

Figure.19- Contrast of render effect of illumination

Source: Complied by the author using Unity

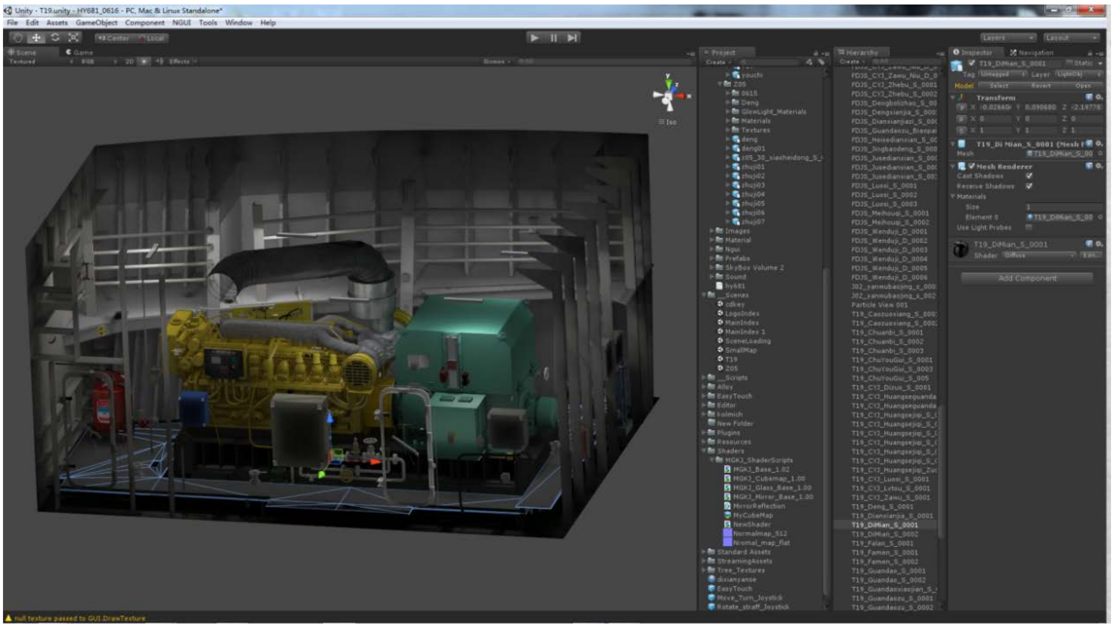

Figure.20-Generator room using the default shader diffuse rendering

Source: Complied by the author using Unity

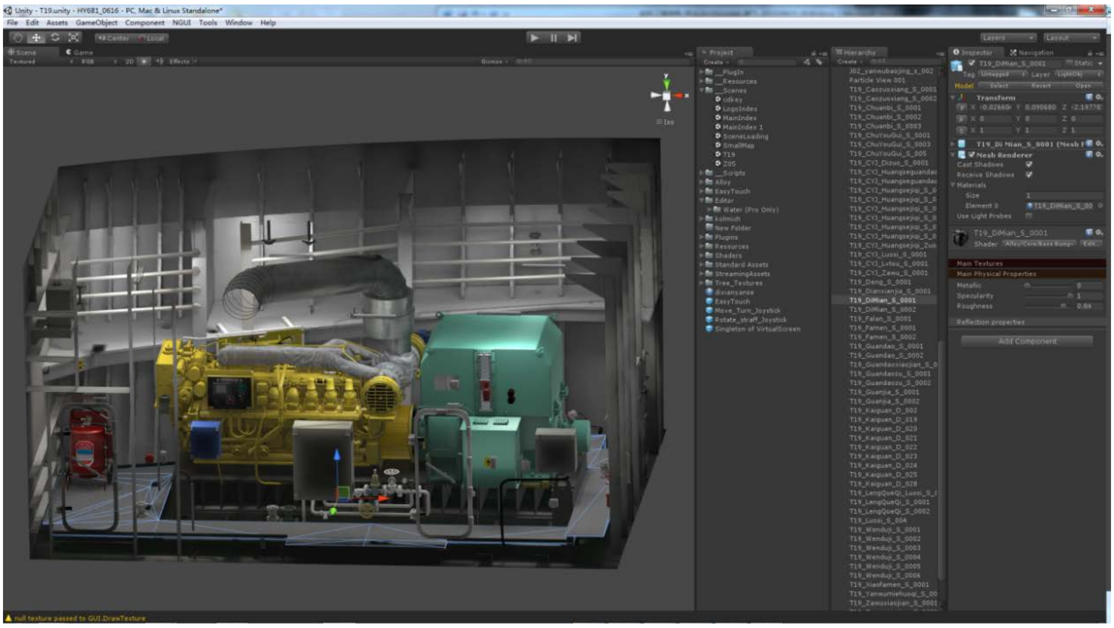

Figure.21-Generator room shader after dimming

Source: Complied by the author using Unity

It can be seen by rendering that Lambert model can appear inflexible, showing no luster when rendering the objects made of metal material. The main reason is that it doesn't take the effect of specular reflection into account. So the phong model has a good supplement for it. Because the Blinn-phong lighting model has mixed with the diffuse parts and standard highlights of Lambert, so rendering sometimes is stronger than Phong. However, because the Blinn-phong illumination model has saved two multiplications when calculating the direction vector of reflect light, so it is faster, thus it becomes the default lighting rendering method in many CG software.

4.2 Collision detection

Collision detection technology has been one of the key technology in the field of virtual reality research, the pros and cons of collision detection effect will directly affect the degree of realistic of three-dimensional scene, and then it will affect the immersive of user in 3 dimensional scene (Klosiwski, 1998).

Sometimes we need to reflect the real sense of 3D virtual scene. 3D virtual scene is like the real world scene, objects can't penetrate each other, which would require the collision detection between two objects. The so-called collision detection is refers to whether the intersection has happened during different objects in 3D virtual scene. In 3D scene, all objects are described by the collection which consists of multiple polygons. So according to the knowledge of space geometry, collision detection is the problem to get a given set of intersection. There are a lot of collision detection algorithms, in which space partition method and the bounding box are commonly used (Xiong, 2000).

4.2.1 Space partition method

Space partition method, just as its name implies, is to divide the whole 3D virtual space according to certain rules. So that it makes the different objects in different space. There will be no collision in the space that is not divided into objects, the useless collision detection can be removed out, and there may be a collision in the rest of space that is divided into objects, then it needs next step of collision detection. Space division method mainly includes the partitioning method, Quad tree, BSP tree, Oct-tree method.

4.2.2 Bounding box technology

Bounding box is to use simple geometric shapes as the most closely to surround the complex objects in virtual space, and by detecting the degree of cross bounding boxes, we can decide whether the next object collision detection is necessary. If the bounding boxes of two objects do not have any intersection, then the two objects do not collide. Conversely, if there is intersection, we need to perform collision detection between objects. Since the model of bounding box is relatively simple, it is easier to make detection calculations between the bounding boxes. So you can quickly eliminate objects of no collision, which will greatly shorten the time of collision detection. There are commonly used bounding volumes: AABB, OBB, k-dops, sphere (Klosiwski, 1998).

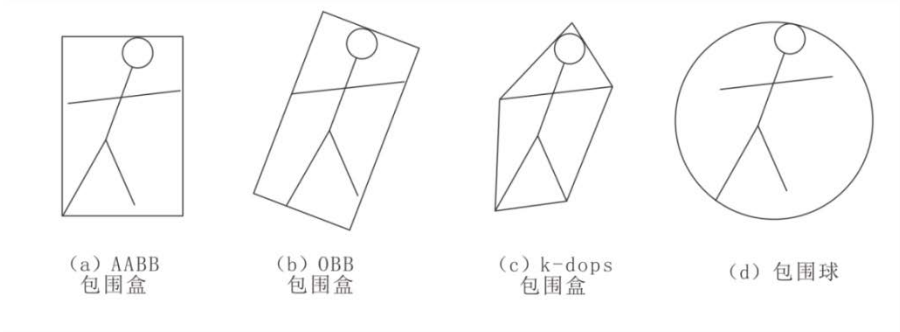

Figure.22- Type of bounding box

Source: the author

（1） Axis Aligned Bounding Box

AABB is the bounding box which is along the axis. It is one of the most widely used bounding boxes. In three dimensions, axis aligned bounding box is the six-sided rectangular bounding box whose direction of the axis is same as respective reference axis. The given objects must all be included in the enclosed box. AABB contains the area as:

$$R=\{(X,Y,Z)|x_{min}\le X\le x_{max},y_{min}\le Z\le y_{max},z_{min}\le Z\le z_{max}\} \quad (4\text{- }10)$$

（x_{min}, x_{max}），（y_{min}, y_{max}），（z_{min}, z_{max}）respectively represent the minimum and maximum values of the object in the xyz axes. It can also come from the expression that only when AABB bounding boxes are intersecting in every projection interval of three axes, the two AABB are intersecting.

（2） Oriented Bounding Box and k-Dops Bounding Box

Unlike the axis aligned bounding box, Oriented bounding box's orientation axis is arbitrary. It can surround object as tightly as possible based on the external shape of the object, which increases the complexity of collision detection. K-Dops bounding box is also known as discrete directed polyhedron or PDH (Fixed Directions Hull) .It is defined as containing the object and the surface around the normal vector are taken from the convex hull of a set of fixed direction, in which the direction vectors are collinear and opposite vector pairs. Oriented bounding box and k-Dops bounding box both have high degree of difficulty in collision detection and complexity of structure, which consume a lot of computer system resources, and are not suitable for large-scale virtual scenes.

（3） Sphere

Sphere is similar to the bounding box above. It is also a kind of commonly used bounding volume, just as its name implies, is the smallest sphere space that can put the objects contained inside (Ritler,1990). The expression of three dimensional space it occupied is:

$$R=\left\{(x,y,z)|(x\text{-}c.x)^2+(y\text{-}c.y)^2+(z\text{-}c.z)^2\leq r^2\right\} \quad (4\text{- }11)$$

Among them, the R is the space of Sphere, r is the radius of the space of Sphere.

In the actual calculation, if the required calculation results are not very accurate, we need faster computing speed and take less consumption of resources. We can get an approximation sphere by calculating the maximum and the minimum of vertex coordinates of the model. The average of the maximum and the minimum of vertex coordinates of the model can locate the sphere center. Assume that the maximum and the minimum of vertex coordinates of the model are:

$(x_{max},y_{max},z_{max})$ and $(x_{min},y_{min},z_{min})$, (C_x,C_y,C_z) is the center of sphere，then the center coordinates of sphere (C_x,C_y,C_z) are: $C_x=\frac{1}{2}(x_{max}+x_{min})$, $C_y=\frac{1}{2}(y_{max}+y_{min})$, $C_z=\frac{1}{2}(z_{max}+z_{min})$

The radius of the space of Sphere is: $r=\frac{1}{2}\sqrt{(x_{max}\text{-}x_{min})^2+(y_{max}\text{-}y_{min})^2+(z_{max}\text{-}z_{min})^2}$

Collision detection between the spheres is simpler, calculating the distance between the two cores and compared with total radius. If it is bigger than the total radius and it will not impact. If it is less than the total radius, the collision would happen. The advantage of Surrounded ball is that the structure is simple besides collision detection method is simple. When object rotation occurs, the surrounded ball will not be affected, as long as it doesn't translate and needn’t to undertake heavy alignment calculation and less occupied resources (Ritler,1990).

4.3 3D Pick up

Cabin in the virtual scene, there are many valves, buttons, telegraph and movable virtual objects, In order to realize the simulation and allow users to have a better experience and interact with two-dimensional simulation software at the same time. The software need to pick up on these virtual components. The pickup of object in this article is implemented by ray pick algorithm, and this algorithm is also currently the most basic algorithm in virtual scene.

Basic on the principle: when click a mouse trigger screen a point to obtain the coordinates on the screen, the coordinates is then transformed into viewport coordinates, then add depth to the coordinate value and then that point coordinate values in the world coordinate system is obtained by inverse operation, the last point of view as the starting point, to the point at which lead a ray and the space objects according to the depth of each intersection, if only one object intersection, then the object is needed to pick up, if there are multiple objects intersections, the smallest object depth is for pick up.

The principle shows that there are two key steps to implement the algorithm on pick up: the first is transform the object on the screen of the coordinates on the plane into the coordinates of the point on the 3 d virtual space, then using ray intersection with things picking algorithm .The following shows the specific description:

(1) pick up point coordinates on the screen, conversion of coordinates to get the corresponding projection screen space coordinate points in the window . W is the viewport width, the height is H, the coordinates of the mouse capture point is (x, y), coordinates of projection window is $P_n = (P_{nx}, P_{ny}, P_{nz})$, the 0 point on the left upper corner of the viewport coordinates is x = y = 0, viewport matrix:

$$\begin{bmatrix} \frac{W}{2} & 0 & 0 & 0 \\ 0 & -\frac{H}{2} & 0 & 0 \\ 0 & 0 & Z_{max}-Z_{min} & 0 \\ X+\frac{W}{2} & Y+\frac{H}{2} & Z_{min} & 1 \end{bmatrix}$$

By the projection window point P0 viewport transformation to obtain the point on the screen O:

$$x=\frac{W}{2}(P_{nx}+1) \quad (4\text{- }12)$$

$$y=\frac{H}{2}(1-P_{ny}) \quad (4\text{- }13)$$

Inverse transformation:

$$P_{nx}=\frac{2x}{W}-1 \quad (4\text{- }14)$$

$$P_{ny}=-\frac{2y}{W}+1 \quad (4\text{- }15)$$

Z is the value of depth, only affect the location of the P_n on the ray, value range of [0,1], when z = 0, said P_n point near the cutting surface; When z = 1, said the P_n on the far clipping.

(2) Calculating the inverse transpose matrix after projection matrix and point matrix multiplicated, converse P_n coordinate to world coordinate system.

At this point, Pw can be calculated by in the world space coordinates:

$$(P_w,1)=(P_n,1)\cdot(M_w\cdot M_v\cdot M_p)^{-1}$$

M_p is the projection transformation matrix, M_v is the viewpoint of transformation matrix, M_w is transformation matrix to the world.

(3) Determine the ray equation with points on the P_c and ray P_w:

$$P_{(t)}=P_c+\frac{P_w-P_c}{\|P_w-P_c\|}t \qquad (4\text{- }16)$$

(4) Determine whether a ray and objects intersect.

To simplify the process, improve the running speed, surrounded ball are chosen on objects. c is ball coordinates, radius r, then intersection situation can be desided:

$$\|P_t-c\|-r=0 \qquad (4\text{- }17)$$

$\frac{P_w-P_c}{\|P_w-P_c\|}$ is the unit vector, therefore, $(\frac{P_w-P_c}{\|P_w-P_c\|})^2=1$ then transform it into a yuan quadratic equation to solve the problem:

$$t^2+2\left(\frac{P_w-P_c}{\|P_w-P_c\|}\right)(P_c-c)t+(P_c-c)^2-r^2=0 \qquad (4\text{- }18)$$

If the equation has a positive solution, suggests that ray fellowship with defend the ball which pick up on the object.

4.4 Conclusion

Introduced on the shaders and Unity built-in shaders is the first in this chapter. Then rendering of the same object with lighting model custom shaders to real-time, and compared with the renderings. And then realize the collision detection used in the engine room and virtual scene, also 3 D pick up technology are studied.

Chapter 5 Implementation of communication between 2D simulator and 3D virtual engine room

The explosive development of computer technology in various industries, virtual reality technology has been introduced into the turbine simulation of the ship. Development methods of the design staff become more and more, so it improves the maturity and authenticity of the turbine simulation greatly. Beneficiaries will eventually become marine engine room simulator end users. Virtual reality technology is the further development of 3D technology. It can provide users with the feeling of visual, hearing, touch, and smell which is close to the real environment. Turbine 3D virtual simulation system should include the ship engine room scene roaming and it should also be combined with virtual reality interactive technology and network technology to achieve the realization of virtual operating of the engine system and turbine equipment. Then we can provide the end users with operation and learning platform of turbine simulation. The 3D virtual simulation system of engine room in this paper is the combination of three dimension visual technology and interactive technology and network transmission technology. It also combines the state of mathematics and logic model in the background of 2D marine engine room simulator software and virtual device status of 3D engine room. Then under the condition that data is consistent with 2d simulator software, to realize the functions such as virtual roaming in virtual engine room, virtual operating system equipment and equipment parameter display (Luo, 2008).

5.1 Summary of network communication protocol

Network protocol is to set up communication channels and the rules to control the flow of information on the Internet. It makes the rules which includes the format of the data unit which need to transfer, the information meaning of information unit, the connection mode of communication on both sides and timing of sending and receiving. It is used to ensure uniformity, accuracy and reliability of the network data transmission. The communication protocols in local area network mainly include TCP/IP, NetBEUI and IPX/SPX agreements. Each protocol has its application environment (Shang & Liu &.Zheng, 2003).

1. NetBEUI

NetBEUI was developed by IBM. It is a kind of small volume, high efficiency and high speed communication protocol. NetBEUI is specifically designed for single segment departmental in small local area network which consisted of several to hundreds of PC. It does not have the ability to work across a network segment, in other words, NetBEUI does not have routing functions. Although there are many unsatisfactory points in NetBEUI, it also has its advantages which other agreements do not have. In the three kinds of communication protocols, NetBEUI has minimum memory and it almost does not need any configuration in the network.

2. IPX/SPX and the compatible agreement

IPX/SPX (Internetwork Packet exchange/Sequences Packet exchange) is a set of communication protocols of Novell company. When compared with NetBEUI, a significant difference is that IPX/SPX is relatively large and has strong adaptability in complex environment. IPX/SPX has considered about the network segment at the very beginning of the design. It has strong routing functions and it is suitable for large networks. In the IPX/SPX protocols, IPX is at the bottom of the NetWare agreement, and it is only responsible for moving data in the network. If does not guarantee whether data transmission is successful and does not provide error correction service. When the IPX is responsible for the data transfer, if the receiving node is in the same network segment, it will transfer the data to the node directly according to the node ID. If the receiving node is remote (not in the same network segment, or located in different local area network (LAN), the data will be handed over to NetWare servers or routers in the network ID, then continue the next step of data transmission. SPX is responsible for error-free processing of data transmission in the agreement, so IPX/SPX is also called Novell agreement sets (Shang & Liu &.Zheng, 2003) .

3. TCP/IP

TCP/IP（Transmission Control Protocol/Internet Protocol）is one of the most commonly used communication protocols currently. It is a common protocol in the computer world. It is also the foundation of the Internet protocol at the same time. TCP/IP has high flexibility and supports any size of network. It almost can connect all the server and the workstation (Jiang, 2003). Just as the IPX/SPX and its compatible protocol, TCP/IP is a routable protocol. However, there are some differences. TCP/IP address is classified which makes it easy to determine and find online user and improve the utilization of network bandwidth at the same time. When required, TCP/IP protocol server (such as Windows NT server) can also be configured to be TCP/IP router. Unlike TCP/IP, the IPX of IPX/SPX protocols is a broadcast protocol. It often has jams of broadcast packets, so we cannot get the best network bandwidth.

There are two tied protocol in the transport layer of TCP/IP protocol architecture. They are TCP and UDP. The TCP is a connection-oriented, and supports a connection-oriented and reliable transport service between the two TCP endpoints. UDP is a connectionless and unreliable transmission service between two UDP endpoints. Each protocol has its advantages and disadvantages. We should choose the appropriate communication protocol according to our demand. In this paper, we choose the UDP protocol in TCP/IP protocol architecture to complete the 3D virtual reality and communication interaction between 2D simulator according to the requirements of transmission efficiency and response time (Zhao&Ye, 2006).

5.2 realization of data communication protocol

5.2.1 Socket

Socket is the communication abstract point in the process. In the computer world, two programs use the Socket to communicate. Two programs communicate through a two-way communication link on the Internet. Each side of the two-way link becomes a Socket. Socket actually provides a communication port on the computer. We can communicate with any computer which has a socket interface through this port. The application transfer information and receive information on the network through the Socket interface. Just like the use of a file handle, we can read and write the handle of a socket in the application development.

There are three ways to communicate using the socket:

1. Byte stream Socket (StreaSocket): TCP protocol in the TCP/IP protocol uses this interface. It provides a connection-oriented, error-free, unlimited length and none-repeat network packet transmission；
2. Datagram Socket: UDP in the TCP/IP protocol uses this interface. It is a connectionless service and transfers the information in package on the network. The maximum length of the pack is 32 KB. This transmission does not guarantee order, reliability and repeatability (Zhao&Ye, 2006). It is normally used for a single packet transmission or the occasion whose reliability requirement is not high；
3. Raw packets socket: It provides direct access to the lower network communication protocol (such as TCP/IP protocol). It is generally not for ordinary users and it is mainly used for the development of new protocol or used to extract the hidden function.

5.2.2 The principle to implement UDP

UDP is a connectionless communication protocol. When sending data, the client does not need to establish a connection, he just needs to know the recipient's IP address and port number.

Several properties of the UDP protocol：

(1) UDP does not need to establish the connection between source side and terminal side. It is a connectionless protocol. The speed which UDP transmit data will be

influenced by the data speed of application generated, transmission bandwidth limitations and the computer power.

(2) UDP is a connectionless protocol. It allows that a server machine can send the same message to multiple client machines at the same time.

(3) UDP does not guarantee the reliable delivery of data, so the host does not need to maintain the complex link state table.

(4) UDP packets only have the title of 8 bytes. It is very small when comparing with the TCP 20 bytes of TCP.

1. The protocol format of UDP

In this paper, we use UDP protocol to achieve the communication between 3D virtual reality and two-dimensional simulator. The interaction point of ship simulator mainly includes button, indicator light, shift knob, instrument, sensors and so on. C # programming mainly includes four types, the bool type, int type, float type, and string type. In different host application communication data need to be exchanged and transferred according to datagram format of the definition of UDP. Therefore, in order to ensure accuracy of data, self-defined datagram format is needed. The following diagram is the specific format of the self-defined protocol.

2. Implementation procedure of UDP

UDP datagram protocol which Socket uses is connectionless. A datagram is an independent unit and it contains all the information of this delivery. Image it is an envelope and it has the destination address and the content to be sent. In this mode, Socket does not need to connect another Socket. It just simply throws a datagram.

5.3 Realization of the interaction between 3D virtual engine room and 2D simulator

In order to achieve better operating simulation and visual effects of marine engine room simulator，we make virtual engine room and the two-dimensional marine engine room simulator achieve real-time communications and then realize the interactive operation.

The communication between 3D virtual engine room and the two-dimensional marine engine room simulator is to achieve the following purposes：

1. By operating 3D virtual equipment in engine room, real-time state of equipment will make corresponding change. The condition of two-dimensional marine engine room simulator will also make corresponding changes through data communication.
2. By operating the equipment of two-dimensional marine engine room simulator, real-time state of equipment will make corresponding change. The condition equipment of 3D virtual engine room will also make corresponding changes through data communication.

Network communication between 3D virtual engine room and the two-dimensional marine engine room simulator uses the UDP protocol in this paper. The system data in two-dimensional simulator software will turn into an array through serialization. The data will be sent to 3D virtual engine room every 0.2s at a time. However, 3D virtual engine room send data to the two-dimensional marine engine room simulator just when the data has changed. Take the start button of the generator control panel for example to illustrate the process of communication. When operating the start button in virtual engine room, the logic value of the corresponding interactive entities will change, and the data in 3D virtual engine room will change. Then it will send report data to two-dimensional marine engine room simulator. After the simulator receives the datagram, it will change the corresponding data of the simulator software system according to the change of the data. Then call the diesel generator mathematical model and logic model to change the corresponding data and state of generator in two-dimensional simulator, and send data to 3D virtual engine room through two-dimensional simulator software (Shang & Liu &.Zheng, 2003).

When operating the start button of two-dimensional marine engine room simulator, the logic value of the corresponding interactive entities will change. So will the data of the simulator software system. Then call the diesel generator mathematical model and logic model to change the corresponding data and state of generator in two-dimensional simulator, and send data to 3D virtual engine room through two-dimensional simulator software. Virtual engine room side will parse the received data and call the interactive entity movement function to complete response. In this way we can guarantee that the real-time operating status of 3D virtual engine room is consistent with two-dimensional marine engine room simulator. The communication between 3D virtual engine room and two-dimensional marine engine room simulator does not need third party software platform. All model calculation data of the simulator is stored in the installation PC. The real-time status updating is using the UDP protocol and virtual engine room side.

5.4 Conclusion

This chapter mainly introduces real-time communication interaction process between the three-dimensional virtual engine room and two-dimensional simulator. We use a connection-oriented UDP protocol considering the real-time requirement for communications transmission speed. We use Microsoft Visual Studio c # medium Socket to achieve sending and receive in real time, achieving real-time synchronization of data and state between the two-dimensional simulation software and 3D virtual engine room. This provides a guarantee for the collaboration between training and training effect.

Chapter 6 Conclusion and prospect

This paper has completed the virtual scene modeling and optimization of the cabin, development and interaction of unity custom shader and interaction between two-dimensional simulator and 3D virtual scene. this paper's main work is as follow：

1. Using 3ds Max to make engine scene modeling and summarizing the modeling standard and rule of optimization. This paper mainly introduces the normal mapping technology in texture optimization and gives the example of virtual engine room scene which uses normal mapping.
2. Using the Unity shader technology. This paper introduces Lambert, Phong, Blinn Phong and attenuation Blinn Phong illumination model. Then making custom Unity shader according to these illumination models to improve the effect of virtual scene rendering in virtual scene.
3. Doing a research of the Unity collision detection technology and 3D pick up technology and edit code to complete 3D interaction. The implementation of scenario dynamic loading is to improve the system operation.
4. Finishing the interaction between 2D simulator and 3D interaction of virtual engine room by using the UDP communication protocol.

Although this paper has completed the design and interaction of virtual simulation system, the engine system is too big and complex. This virtual design is too extensive and my knowledge is limited. Due to lack of experience and time constraints, this topic has many points to improve. Specific summary is as follows.

(1) Aspects of modeling: model needs to be further optimized. In addition to normal mapping technology, other technology such as other mapping technology Alpha map, height map can also be used to optimize the mode. In addition, we can also use more appropriate technical methods such as LOD detail technology to balance model scale and speed.

(2) Aspects of shader: Custom Unity shader development is not a very complicated process, but the shader optimization is very complex. An excellent shader can greatly increase the realism of virtual scene, so the development and optimization of shader is a further subject.

References

Badt S Jr. (1988). Two algorithms taking advantage of temporal coherence in ray tracing[J]. The Visual Computer, 4(3): 123-132.

Blinn J F. (1977). Models of light reflection for computer synthesized pictures. Computer Graphics, 11(2): 192-198.

Cao, H. & Zhang J. D. (2012). The application and development of modern marine engine room simulator. Maritime Education Research, (01): 33-36.

Chen J. X. & Zhou W. J. (2002). An improved Phong model and it's algorithm of ray-tracing[J]. Acta Simulation Systematical Sinica, 14(12): 1642-1643.

Dou X. D. & Zhang W. (2010). 3ds Max 2010: the Legend of VRay render. Beijing: China Youth Press: China Youth Electronic Press.

He Z.B. & Zhang J.D. & Lin Y.J.(2007) Marine engine room simulator development and comparative research in china and foreign countries. Shipbuilding technology. (1)：38-40

Huang Z. Z. (2009). Virtual reality technology in the application of crew training education. Maritime Education Research, 4: 78-79.

Jiang D. X. (2003). *The fundamental of TCP/IP and UNIX web service*. Tsinghua University Press.

Kilgard M J. (2000). A practical and robust bump-mapping technique for today's GPUs. Game Developers Conference.

Klosiwski J. T. & Held M. & Mitchell J. S. B. (1998). Efficient collision detection using bounding volume hierarchies of k-dops. IEEE Transactions on Visualization and computer Graphics, 4(1).

Kniss J, Premoze S, Hansen C,et al. (2003). A model for volume lighting and modeling. Visualization and Computer Graphics, IEEE Transactions on, 9(2): 150-162.

International Maritime Organization. (2015). International Convention on Standards of Training, Certification and Watchkeeping for Seafarers(STCW). Retrieved April 10, 2015 from the World Wide Web: http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-on-Standards-of-Training,-Certification-and-Watchkeeping-for-Seafarers-(STCW).aspx

Li J. J. (2014). Indoor building 3D modeling and interactive system implementation based on Unity3D[C]. Xuzhou: China university of Mining and Technology.

Luo X. (2008). Reaserch on data communication of ship integrated monitoring system[C]. Dalian: Dalian Maritime University.

Ritler J. (1990). An efficient bounding sphere. Graphics gems. Academic Press Professional, 301-303.

Shang Z. G. & Liu X. G. & Zheng K. (2003). Reaserch and Implementation of interactive walkthrough in 3D scene. Computer Engineering, 29(2): 60-63.

Shen H. S. (2013). Virtual design of VLCC marine engine simulator[C]. Dalian: Dalian Maritime University.

Sorensen Kim. Condra T. Modeling and simulating fire tube boiler performance. Proceedings of SIMS 2003-44th Conference on Simulation and Modeling, 2003: 9-12.

Unity scripture. (2012). Shaders. Retrieved April 5, 2015 from the World Wide Web: http://game.ceeger.com/Manual/Shaders.html.

Watt A H, Watt A. (2000). 3D computer graphics. Reading:Addison-Wesley.

Xiong Y. M. (2000). Research on the technology of collision Detection for object in virtual environment[C]. Shanghai: Shanghai University.

Zeng H. (2012). Reseach on visual simulation technology applied in marine engine room simulator[C]. Dalian: Dalian Maritime Unifversity.

Zeng H. & Zhang J. D. & Ren G. (2014). Design and implementation of marine engine room three-dimensional visual simulation system. Journal of System Simulation, 26(2): 363-368.

Zhang K. C. (2014). Virtual reality design and research of ship compressed air system[C]. Dalian: Dalian Maritime Unifversity.

Zhang R. H. (2008). Application of geometric modeling technology in development of virtual campus walkthrough system. Computer Engineering and Design, 23(4):23-25.

Zhang Y. Y. (2011). The mathematical methods in the normal mapping technology of 3D games[J]. Computer knowledge and technology, 8(32): 8043-8045.

Zhao F. & Ye Z. (2006). Contrast analysis of UDP and TCP and improvement of UDP in reliability. Computer Technology and Development, 16(9): 219-221.