Research on ship power system design and control simulation based on Unity3D

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ABSTRACT

Aiming at solving the problem of power system simulation in the construction of ship maneuvering simulator, this paper modeled the power system of 7000DWT ship and completed the model simulation display in Unity3D. A set of user interface of ship handling system satisfying ergonomics is developed by modeling and simulating ship handling system. According to the final simulation results, the data of the real ship and that of the simulation are within the allowable error range, which can well observe the scene in which the navigation condition of the ship changes due to the adjustment of the bell on the Unity3D interface.

Keywords: Unity3D, power plant, mathematical model, ship driving simulator

1. INTRODUCTION

In the totality of ship simulation, simulation of the main power system unit is a very important part. However, there are many inevitable difficulties using computer simulation technology in the study of ship's main power system. With the knowledge of Marine power system equipment, we can use the method of computer simulation, through some software test simulation. In addition, most of the research and development of ship driving simulators at home and abroad are based on the secondary development of hardware systems[1], which has high development cost. This topic will be developed based on the Unity3D software platform, which can reduce the development cost to a certain extent.

The main research contents are as follows:

(1) Establishment of mathematical model for Marine power plant system;

(2) Design and implementation of power system;

(3) Realization of simulation of control system.

2. ESTABLISHMENT OF MATHEMATICAL MODEL OF SHIP POWER SYSTEM

2.1. Quasi-steady state model of marine power plant system

2.1.1. Building the compressor model. The temperature of the press can be calculated by the following equation[2]:

$$dT_c = \frac{T_a(\pi_c{}^{F_k} - 1)}{\eta_c} \tag{1}$$

Outlet temperature:

$$T_c = T_a + dT_c \tag{2}$$

Pressure at outlet:

$$P_c = \pi_c P_a \tag{3}$$

The rotation of the compressor needs to be driven by the shaft of the turbocharger, which requires the following torque:

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International Conference on Computer Application and Information Security (ICCAIS 2021), edited by Yingfa Lu, Changbo Cheng, Proc. of SPIE Vol. 12260, 122601T · doi: 10.1117/12.2637372

$$Q_c = \frac{C_p G_c dT_c 30}{\pi N_c} \tag{4}$$

2.1.2. Establishing the intercooler model. The outlet pressure of the compressor is represented by p_c; The pressure at the outlet end of the intercooler is represented by p_i; T_{ci} is the outlet temperature of the intercooler; K_{cp} is the actual diesel data.

Outlet temperature of intercooler:

$$T_{ci} = T_c - \varepsilon(T_c - T_w) \tag{5}$$

Pressure of intake pipe:

$$p_i = p_c - K_{cp} G_i^2 \tag{6}$$

2.1.3. Building the Cylinder Process Model. Suction flow G_{i1} plus scavenging flow G_{i2} is the flow through the intake valve G_i, therefore:

$$G_i = G_{i1} + G_{i2} \tag{7}$$

Suction flow:

$$G_{i1} = \frac{\eta_v V_s n P_i}{120 R T_i} \tag{8}$$

In the quasi-steady state model, the average value of the flow section is

$$G_{i2} = A_v p_i \varphi \sqrt{\frac{2k}{(k-1)RT_i}} \tag{9}$$

$$\varphi = \sqrt{\left[\pi_{ei}^{\frac{2}{k}} - \pi_{ei}^{\frac{k+1}{k}} \right]} \tag{10}$$

This paper adopts the set scavenging coefficient. The calculation method is shown in the equation below:

$$G_i = \phi_s G_{i1} \tag{11}$$

The values of Φ_s can be derived by fitting with actual test data.

2.1.4. Diesel Engine Ontology Modeling. As for the effective output torque Q_e of diesel engine, the calculation method of effective torque is as follows:

$$Q_e = \frac{H_u i}{\pi \tau} g_c \eta_e \tag{12}$$

Excess air coefficient:

$$\alpha = \frac{G_{i1}}{L_0 G_f} \tag{13}$$

G_{i1} represents the suction flow of the diesel engine: G_f represents the mass flow rate into the cylinder:

$$G_f = \frac{Fn}{30\tau} \tag{14}$$

2.1.5. Exhaust temperature of the cylinder. In general, the value *n* of diesel engine speed and the total air-fuel ratio *AFR* are closely related to the exhaust temperature *Te*:

$$Te = \Delta Te + Ti \tag{15}$$

$$\Delta Te = \frac{(1-\eta_i)H_u / C_{pe}}{1+AFR} \tag{16}$$

2.1.6. Establish injection pump model. There is also a certain relationship between the fuel supply per cycle and the oil pump camshaft speed (diesel engine speed). Thus, the linear relationship between the circulating oil supply and rack displacement is obtained as follows

$$\frac{g_c - g_{c0}}{g_{ch} - g_{c0}} = \eta \tag{17}$$

2.1.7. Turbine modeling. To simplify the model, consider the turbine as a nozzle:

$$G_t = Ae\frac{p_t}{\mathrm{Re}T_t}\sqrt{\frac{2k_e}{k_e-1}(\frac{p_a}{p_t})^{2/k}\left[1-\left(\frac{p_a}{p_t}\right)^{(k_e-1)/k_e}\right]} = \frac{f_1(p_t)}{\sqrt{T_t}} \tag{18}$$

In order to calculate turbine flow more easily, the following equation can be used:

$$G_t = G_i + G_f \tag{19}$$

When the turbine rotates, the torque generated can be calculated using the following formula:

$$\mathrm{Q_t} = \eta_t \frac{k_e \mathrm{R_e}}{k_e - 1}\frac{30}{\pi}\left[1-(\frac{p_a}{p_t})^{\frac{k_e-1}{k_e}}\right]\frac{G_t T_t}{n_{tc}} \tag{20}$$

Supercharger speed n_{tc} is expressed as:

$$\frac{\pi}{30} I_{tc} \frac{dn_{tc}}{dt} = Q_t - Q_c \tag{21}$$

2.1.8. Shafting dynamics model. The speed of diesel engine is calculated according to the following equation:

$$\frac{\pi}{30} I_d \frac{dn_d}{dt} = Q_e - Q_{ms} - M_p \tag{22}$$

2.2. Paddle model

2.2.1. Mathematical model of propeller. When the propeller is rotating, the thrust and water resistance moment can be calculated as follows:

$$T_p = K_t \rho {n_p}^2 D^4 \tag{23}$$

$$M_p = K_q \rho {n_p}^2 D^4 \tag{24}$$

In practice, propellers are usually mounted at the rear of the hull, which causes a thrust reduction effect:

$$P = T_p(1 - t_p t) \tag{25}$$

2.2.2. Creating a hull model. In the process of sailing, the ship will be affected by resistance, which can be divided into vortex resistance and wave resistance. The following formula can be used to calculate ship resistance:

$$R = rV_s^{\,z} \tag{26}$$

The following formula can also be used to calculate ship resistance:

$$R_s = \frac{1000P_e}{v_s} \tag{27}$$

Ship speed v_s in dynamic simulation is calculated as follows:

$$k_w m \frac{dv_s}{dt} = ZP - R \tag{28}$$

In this expression, k_w means water retention coefficient; m means the overall mass of the ship.

3. POWER SYSTEM PROGRAMMING

In this design, the clock variables, ship speed, sailing speed and other variables should be adjusted. By changing the clock, the speed of the ship changes. The results are shown in Figure 1.

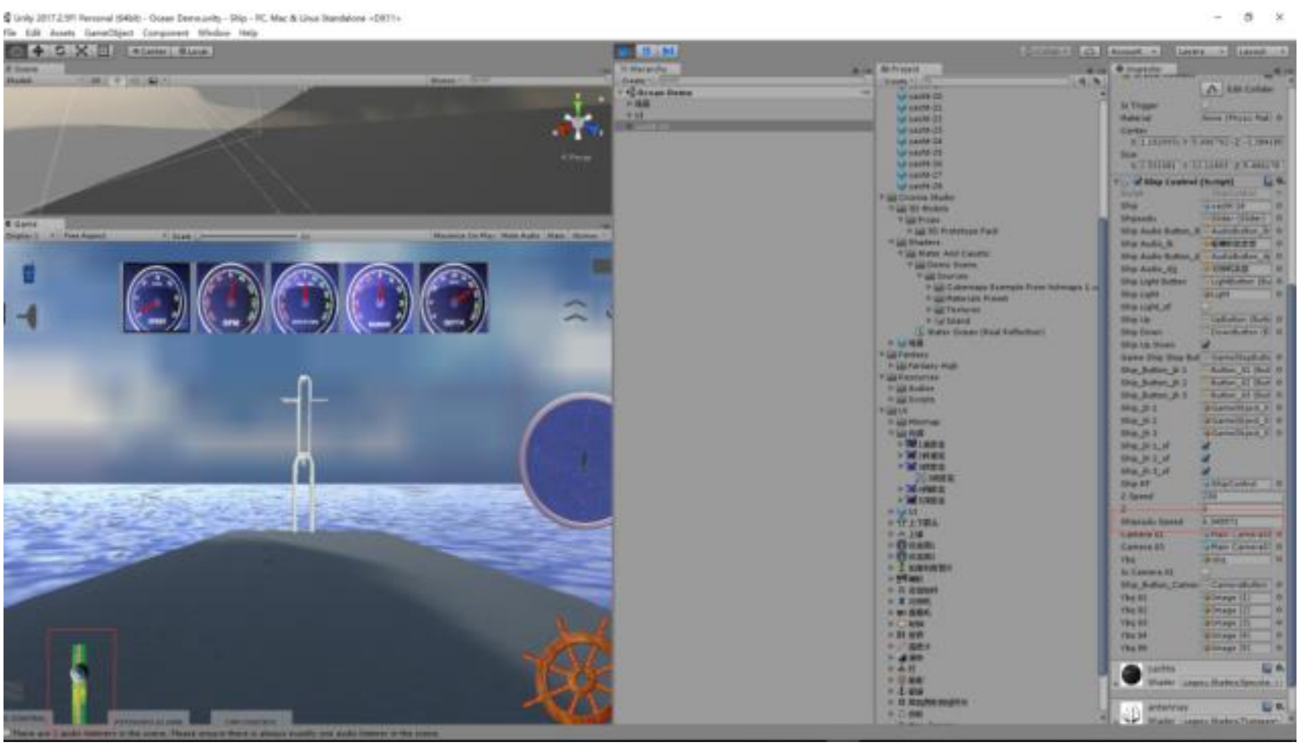

Figure 1. Simulation results.

4. THE CONSTRUCTION OF VIRTUAL SCENE

4.1. Construction of solid model

Basic shape modeling, lofting modeling, modifier modeling, polygon modeling and graphics modeling were used to establish the basic model. Then import the FBX file exported from 3D MAX into Unity3D. Because too many models increase the CPU performance burden, it is necessary to minimize the number of models in the scenario and merge multiple models to form a new overall model to reduce the burden[3, 4].

4.2. Construction of virtual ocean scene

In this paper, radioactive LOD grids are used to achieve sea level grid modeling. A level 5 LOD are used and the outermost layer was loaded with a circular Mesh to fill the outermost scene. All Mesh are generated under the Object named Ocean[5]. The partially generated Mesh list is shown in Figure 2.

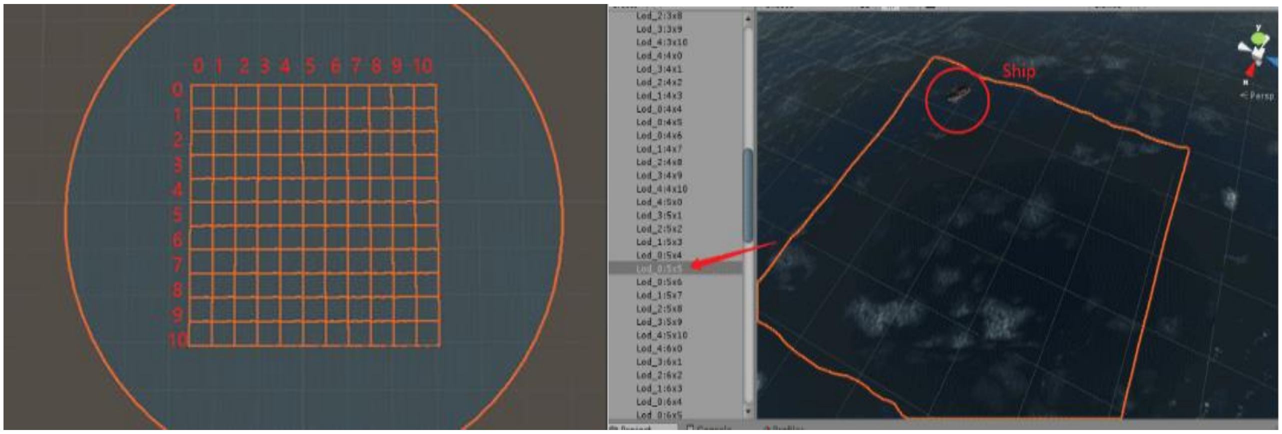

Figure 2. Sea level grid model diagram.

The hull is always within a 5*5 mesh area. The LOD level is LOD_0. Draw the finest details and effects. The rest takes a lower level LOD.

To achieve virtual ocean dynamic effects:

(1) The offset to determine whether to move the Ocean Object is calculated;

(2) The Mesh and select the corresponding LOD level (variable Christ) are generated.

The generated virtual ocean scene and the previously constructed entity model are put into the same scene, and finally the completed virtual scene as shown in Figure 3 is obtained.

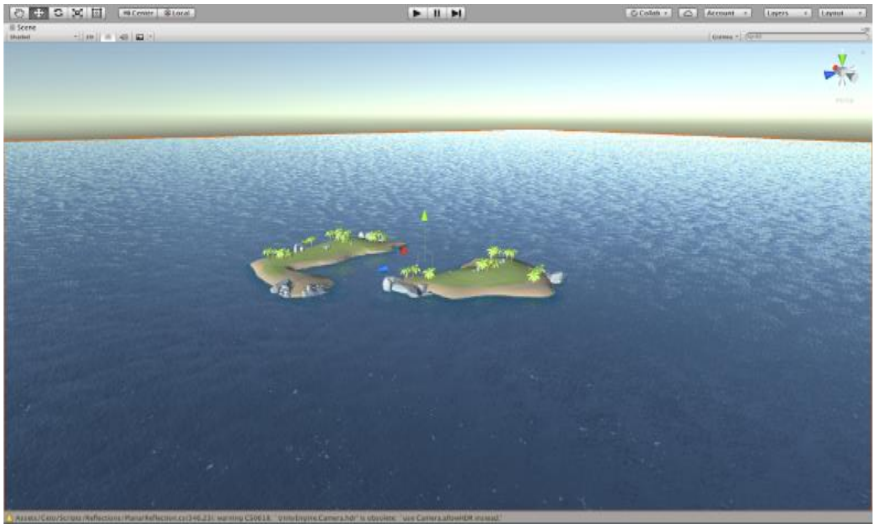

Figure 3. Virtual scene diagram.

5. DESIGN OF SIMULATION SYSTEM

5.1. Interactive interface design

The built-in GUI system of Unity3D is chosen for this topic. The built-in GUI system is used based on Unity3D to create an interactive interface in line with user operation habits[6, 7], which is shown in Figure 4.

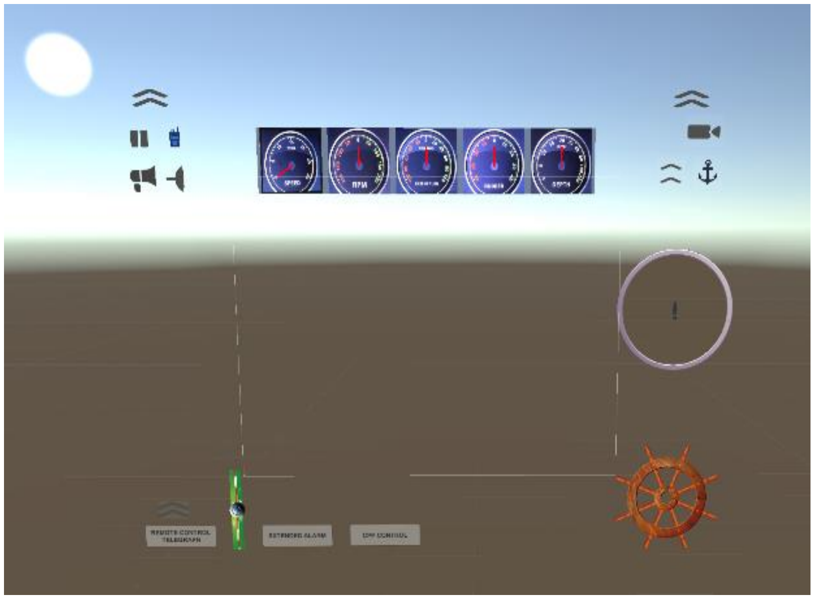

Figure 4. Interactive interface diagram.

5.2. Ship monitoring and alarm system

In terms of monitoring system, several instruments are set up to monitor the running state of the ship in real time to realize the basic monitoring of ship operation. In this project, five different instruments are set up to monitor the ship in real time, including SPEED, RPM, RATE OF TURN, RUDDER, DEPTH.

The interface after running is shown in Figure 5.

In terms of alarm system, this paper takes the simulation training system of ship engine room in Marine Engineering Laboratory of Jiangsu University of Science and Technology as the entity reference model. A set of alarm system is constructed to reflect the ship’s bad operation state through alarm lights. The interface after completion is shown in Figure 5.

Figure 5. Alarm indicator diagram.

6. CONCLUSION

This topic is a more complete design of the Marine diesel engine power plant system mathematical model, in Visual Studio 2017 using C# language to write these mathematical models, integration, and finally complete a power system program. According to the change of rack position, calculate the ship sailing speed, diesel engine speed and other data. Compared with the data of the real ship of 7000 tons, the simulation results are valid within the allowable error range. The simulation system can fully realize the basic navigation and control of the ship.

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