

# The development of TG-8000/8500 gyrocompass simulation system based on Unity3D

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**Abstract**—The expensive price and complicated structure of gyrocompass cannot satisfy the need of present education. This paper analyzed the structure and function of a new type gyrocompass TG-8000/8500. In unity 3D engine, using virtual reality technology to develop this type of gyrocompass simulation system. Lagrange interpolation method has been used to construct interpolation basis functions, and the motion of 3-DOF (degrees of freedom) of system related parts is realized. Through the mass spring model built the simulation of the flexible object and simulated functions of the components in the compass system and the functions of the operation panel. Finally, the generation and publication of the virtual scene are completed.

**Keywords**—TG-8000/8500; Unity3D; mass spring model; simulation

## I. INTRODUCTION

At present, the training of the gyrocompass in maritime colleges and training institutions are mostly used the real equipment, due to complex structure of the gyrocompass and the shortage of equipment<sup>[1]</sup>, the trainees' learning and use are limited, and they can not arbitrarily disassemble and analyze the internal structure, so that the trainees can not accept the effective operation and maintenance training. With the advantages of improving the teaching environment, saving teaching cost and avoiding safety accidents, the virtual reality technology develops well<sup>[2]</sup>. The virtual reality has attracted wide attention in the field of navigation equipment teaching and training. In the research of compass simulation system, Yuan Qunzhe et al have developed a certain type of gyrocompass simulation system in LabVIEW environment, the functions of compass been simulated and realized, but the development of compass is a two-dimensional system, sense of reality is not enough<sup>[3]</sup>. Wu Jianhua and others use VRML language to develop the Ama-Brown MK10 gyrocompass simulation system, showing the gyrocompass's internal and external structure, but its function is insufficient<sup>[4]</sup>. Liu Jingjing developed the Siberian MK37 Gyrocompass and Magnetic Compass using Unity 3D, which is fully functional, but has low

operating efficiency. Based on the research of [1], this paper develops a new gyrocompass TG-8000/8500 by using Lagrange interpolation method and mass spring model by improving the algorithm of compass function. Using Unity 3D engine as a virtual reality implementation tool<sup>[5]</sup>, through the preparation of C# script, to achieve the compass system simulation.

## II. TG-8000/8500 GYRO COMPASS COMPOSITION AND FUNCTION

At present, about 8000 ships has been equipped with the TG series of gyrocompass all over the world. The TG-8000/8500 is a new generation of products designed to improve the design of the TG-5000/6000 gyrocompass, which retains the high reliability of the original product and further enhances the servo performance and interface functions of the device. TG-8000/8500 Gyrocompass belongs to the Sperbury series of gyrocompass. Mainly include the master compass, azimuth, control unit, gyroscope, liquid connector and other components. The main compass is equipped with a sensitive component for providing information on the ship's course. The bearing repeater is used to determine the target orientation. The control unit provides information on the true azimuth, latitude, slew rate, ship speed, alarm and operating switches in various display modes. Gyro ball is used to search north function automatically. The liquid connector is used to generate the control torque. The character of the TG-8000/8500 Gyrocompass: automatic speed error correction function; digital signal processing in line with IEC61162 international standards; long life and follow the IMO standard; have more output signal function and the structure is more compact and reasonable; mainly used in high-speed navigation equipment.

## III. SIMULATION SYSTEM DEVELOPMENT PROCESS AND KEY TECHNOLOGY

### A. Development process

TG-8000/8500 Gyrocompass system mainly includes: two bearing repeater, the master compass, the operation panel box, compass repeater and digital repeater five subsystems. The first step of simulation is to build a three-dimensional model of the entire system. According to the actual size of the compass

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using 3D Studio Max modeling; Use the tools such as PhotoShop to process the captured images and map them in 3ds Max; Importing the modeling. FBX files and maps into the Unity 3D engine, For lighting, camera and collision detection, material baking and other settings, then writing C # script to achieve the various subsystems of the interaction and function. The development flow chart is shown in Figure 1:

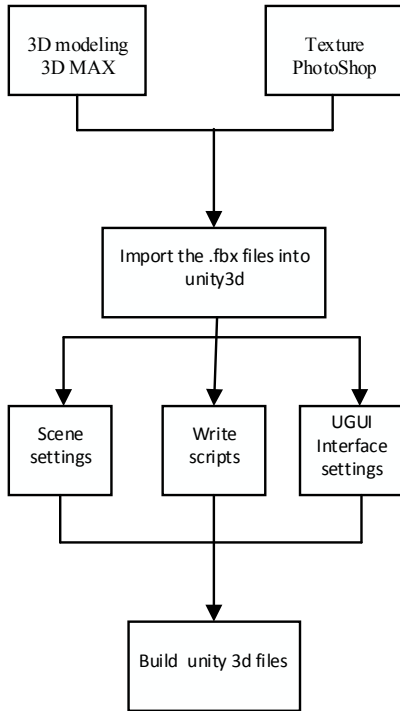


Fig. 1. System development process

## B. Key Technology

### 1) Lagrange interpolation method

In the simulation system, the removal and installation of the compass and the movement of the object and so on, involving the simulation components translation, rotation and other location changes. The system through the numerical interpolation to achieve these changes. In simple terms, given two numerical value (start and end numerical value), the interpolation primary function is constructed by Lagrange interpolation, and the N polynomial interpolation function is solved.

If  $n$  times polynomial  $l_j(x)$  ( $j = 0, 1, \dots, n$ ), the condition is satisfied on  $n+1$  nodes  $x_0 < x_1 < \dots < x_n$ :

$$l_j(k) = \begin{cases} 1, & k = j \\ 0, & k \neq j \end{cases} \quad (j, k = 0, 1, \dots, n) \quad (1)$$

Then call this  $(n+1)$   $n$ -times polynomials  $l_{0(x)}, l_{1(x)}, \dots, l_{n(x)}$ ,

are the  $n$  times interpolation primary function on the nodes  $x_0, x_1, \dots, x_n$ .

$N$  times interpolation primary functions are:

$$l_k(x) = \frac{(x-x_0)\dots(x-x_{k-1})(x-x_{k+1})\dots(x-x_n)}{(x_k-x_0)\dots(x_k-x_{k-1})(x_k-x_{k+1})\dots(x_k-x_n)} \quad (k = 0, 1, \dots, n) \quad (2)$$

The Lagrange interpolation polynomial is:

$$L_n(x_j) = \sum_{k=0}^n y_k l_k(x_j) = y_j \quad (j = 0, 1, \dots, n) \quad (3)$$

$n$  times interpolation polynomials are usually polynomial numbers of  $n$ , Here the value can be the system of numbers, coordinates, angle, object size, object color, volume, etc. Interpolating these values to achieve the translation and rotation of the compass simulation components.

### 2) Mass spring model

The telescopic and moving of wires in the master compass gyroscope simulated as flexible objects. The system adopts the mass spring model to realize the tensile deformation of the wire<sup>[6]</sup>. The position of the particle is affected by the internal spring tension and the external force of the object. For each particle on the rope, all forces acting on the particle can be added to determine the acceleration<sup>[7]</sup>.

$$\begin{cases} m\vec{a} = F \\ m \frac{\partial^2 X}{\partial t^2} = F_i(X, t) + F_e(X, t) \end{cases} \quad (4)$$

In the formula:  $X$  is the particle position vector,  $m$  is the mass of the particle,  $F$  indicating the resultant force of the object,  $F_i$  is the internal force of a particle,  $F_e$  is the external force of a particle,  $X \in R^3$  is solving goal.

In this system, Euler method is used to solve the differential equation of particle motion state in mass spring model<sup>[8]</sup>. Can be obtained:

$$\begin{cases} K_1 = f(t_n, V_n) \\ K_2 = f(t_n + h, V_n + hK_1) \\ V_{n+1} = V_n + h(K_1 + K_2) / 2 \end{cases} \quad (5)$$

In the formula: In the formula:  $f(t_n, V_n)$  is the derivative of speed and time,  $h$  is time step,  $t_n$  and  $V_n$  are current moment status variable,  $t_{n+1}$  and  $V_{n+1}$  are the required of the next state value. A flexible rope is a three-dimensional object with a definite radius. When building the physical model, it is simplified as a spring-connected particle, The three-dimensional drawing of the rope is made by using the method

of polygonal surroundings to form polyhedron<sup>[9]</sup>. Draw the model, as shown in Figure 2:

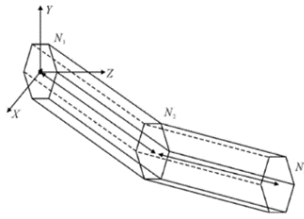


Fig. 2. Wireframe of flexible object

Particle  $N_1$ ,  $N_2$  and  $N_3$  are surrounded by positive  $n$  polygons. In its own local coordinate system. Assume that the Y axis is vertically upward, the formula for calculating the points of a polygon is:

$$\begin{cases} X_i = X_N + r \cos(2\pi i / n) \\ Y_i = Y_N \\ Z_i = Z_N + r \sin(2\pi i / n) \end{cases} \quad (6)$$

In the formula:  $i$  is the sign number of a particle,  $(X_N, Y_N, Z_N)$  is the particle position coordinates,  $(X_i, Y_i, Z_i)$  is the polygon that surrounds the particle, the coordinates of the  $i$  vertex position,  $n$  is the number of edges of a polygon,  $r$  is the radius of the rope.

The polygons calculated in their own local coordinate system are horizontal. In order to make the rope smoother at the point of the curve, we need to calculate the current particle and the previous particle direction vector, use it as the current particle direction.

Calculate the local coordinate system Y axis of the current particle to the rotation vector of the calculation direction. Turns all vertices of the polygon in accordance with this rotation vector, we can get the polygon that eventually surrounds the particle. After determining all vertex positions, determine the vertex order that makes up the triangular surface and add the texture. Finally, the simulation of wire of the gyroscope is realized. As shown in Figure 3:

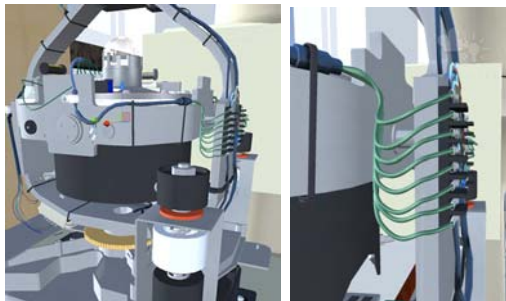


Fig. 3. Simulation of wire on gyro ball

#### IV. TG-8000/8500 GYROCOMPASS SIMULATION

##### A. Master compass module simulation

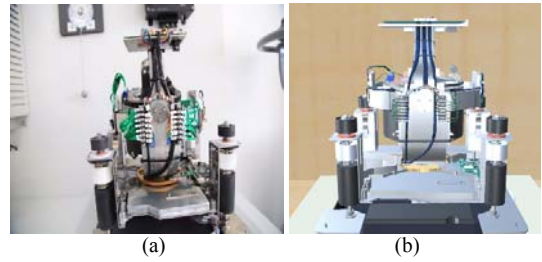


Fig. 4. Gyroscope physical image (a) and simulation image (b)

Master compass interior is gyroscope, it mainly includes gyro wheel, spin axis, horizontal ring, horizontal axis, vertical ring, vertical axis and the base. Figure 4 (a) is the gyroscope physical image, 4 (b) is the gyro simulation image. The gyroscope has 3-DOF of the spin axis, horizontal axis and vertical axis. Two liquid connector devices are installed at both ends of the spin axis of the gyroscope, and the control torque is gained by the gravity difference produced by the flow of liquid in the container. The damping torque is generated directly by applying a damped object on the right west side of the gyroscope.

Implementation: Through the camera to create physical rays, access to the location of the object and other information. Using Lagrange interpolation method to realize disassembly of components such as master compass door, gyroscope, and the screw and so on, and the three degrees of freedom at movement. Through design the UGUI to achieve the course output. Using mass spring model to achieve the wire rotation stretching, deformation and other real-time movement.

##### B. Simulation of the operation panel module

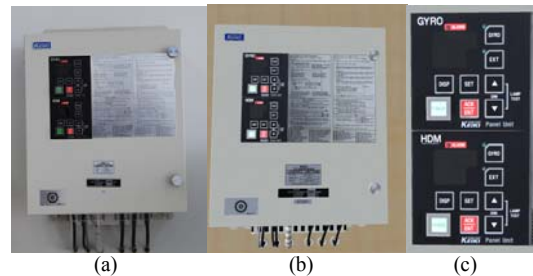


Fig. 5. Operation panel physical image (a), simulation diagram (b), simulation menu (c)

When determine the master compass and the control unit are installed intact, the operator panel is mainly used to display and adjust the data information. Figure 5 (a) is the operation panel physical image, Figure 5 (b) is the operation panel simulation chart, Figure 5 (c) is the operation panel simulation chart menu. The operation panel is divided into GYRO (Gyro-compass) and HDM (Heading Monitor). GYRO and HDM panels also include GYRO data display and EXT (External heading sensor) data display two display modes. Panel interface shows the upper and lower columns, the upper column shows the data of corresponding mode operation, the following column shows the operating mode. DISP is the mode

switch key, used to select the mode and data to be displayed to achieve the instructions of the system switching and data display switch; In the gyro compass mode, there are six display modes: they are SSG (Steering Sensor. Gyro-compass), EST (External Sensor True bearing), CPS(Compass), LAN (Latitude North), SSD (Serial Log Speed), RE (Rate of turn). In the EXT mode, there also have six display modes: they are SSE (Steering Sensor. External sensor), GYT (Gyro-compass true bearing), CPS, LAN, SSD, RE. SET is the setting key used to change the data and input the system. The input data of gyrocompass, such as true azimuth, ship speed, latitude and rotation rate can be adjusted according to the data displayed by GPS, LOG. ACK / ENT is the determined key. In addition to the confirmation of data changes, it can also confirm the system alarm and turn off the alarm beeps.

**C. Bearing repeater simulation**



Fig. 6. Simulation of the bearing repeater dial

The bearing repeater dial is divided into a coarse dial and a precise dial. As shown in Figure 6: The coarse dial shows the integer part of the course, and the precise dial shows the decimal part of the course. Coarse dial a circle turn 10 °, precise dial to 1 °, so it will divide by 36. In the calculation, divide by 10 multiplied by 2π, after that, it's the same of the master dial, then plus the difference of π / 2, the numerical value can be fine-tuned by the calibration knob.

**D. Compass repeater and digital repeater simulation**

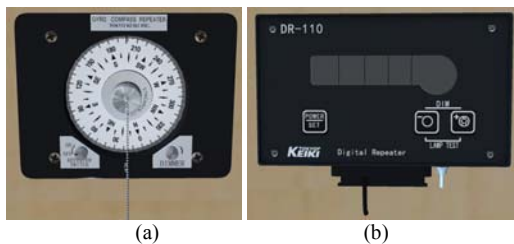


Fig. 7. Compass simulation diagram (a) and DR simulation diagram (b)

The compass repeater is the follower installation of the master compass. Figure 7 (a) is the compass repeater simulation. It has a built-in synchronous receiver. Connected to the synchronous transmitter of the main compass and rotated synchronously with it<sup>[10]</sup>. Displaying the course is the same as the master compass. When you start the gyrocompass system, first check whether the number of the repeater is consistent with the master compass. If there is a deviation, turn the On / OFF knob of the repeater to the OFF position, through turn the middle knob to adjust the display of the repeater is same as the

master compass. And then turn the knob to the ON position, in this position we can not adjust the display of the instrument. The right knob is used to adjust the brightness of the repeater dial.

Figure 7 (b) is the simulation of digital repeater, it shows the heading information of the master compass in numerical form. Its number of changes with the main compass readings change. The display panel brightness is adjustable.

**E. Simulation of three-dimensional laboratory scenarios**



Fig. 8. 3D laboratory scenario simulation

Figure 8 is a three-dimensional laboratory scenario simulation. Put TG-8000/8500 gyrocompass model in lab scene, add lighting effects, add the sky box, bake material, set model collision detection and so on, using C sharp programming language to write interactive manipulation scripts for related objects in the lab. A clock is set in the scene, because of starting the compass system will take a long time, so we set the time of the clock to 6 times the normal clock.

**F. Implementation of the control toolbar**

For ease of operation, the control tool panel is added, including unit store, environment switch and help. We can place the components like bearing repeater doors and screws and master compass door to the unit store. The environment switch is mainly control the night and daytime under the two environments show the scene. Help is TG-8000/8500 gyro compass instructions and precautions. The implementation of the control toolbar is mainly through the UI system, The Unity UI system uses RectTransform to implement basic layout and level control. Graphic is the base class provided by the Unity UI C # library, which is the base class for all Unity UI C # classes. Provides the canvas system with the ability to draw geometric shapes. Use this base class to draw the pop-up dialog box of the toolbar to make human-computer interaction easier.

**V. CONCLUSION**

This paper develops a TG-8000/8500 gyrocompass simulation system based on Unity 3D engine. The structure and function of the TG-8000/8500 gyrocompass are simulated by Lagrange numerical interpolation and mass spring model and other methods. And finally the simulation system is build successfully. The simulation system has a good economic benefits and is practicality, which has brought great convenience to the teaching and training.



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