Research on Obstacle Avoidance of Autonomous Underwater Vehicle in Virtual Environment

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Abstract. With the continuous development and progress of science and technology, the use of virtual environment technology to simulate obstacle avoidance of autonomous underwater vehicles has gradually become a mainstream trend. For this reason, a new type of system has been developed, that is, a visual simulation system for obstacle avoidance of autonomous underwater vehicles. This article analyzed the overall structure of the visual simulation system for AUV obstacle avoidance and the simulation method in the virtual environment, utilized Multigen Creator to conduct AUV modeling, and then used Vega software to establish a three-dimensional ocean scene and set the corresponding target points and object obstacles. Through simulation, it was found that the currently established virtual obstacle avoidance system was very similar to the real environment, and could accurately simulate the underwater obstacle avoidance movement of the vehicle. In the whole process, it could give full play to the function of obstacle avoidance algorithm to the greatest extent, and really provide a certain reference for the obstacle avoidance of related vehicles.

1. Introduction

Autonomous underwater vehicles have now been widely used in civil and military causes, and the main features of autonomous underwater vehicles are intelligence, economy, and long range [1]. The application of autonomous underwater vehicles in navigation is the AUV navigation system, in which the most important thing is the path planning. Path planning is the basis of underwater operations, and it is mainly to plan global paths for environmental prior information and local paths for uncertain environmental sensor information. Generally, when entering the sea, they are in an unknown environment, and they often encounter some obstacles in navigation, so the real-time obstacle avoidance must be considered in navigation. The machine that can realize real-time obstacle avoidance in the AUV navigation system is the forward-looking sonar of the sensor. Through a large number of studies, it is found that in the simulation of AUV obstacle avoidance, the simulation curve is generally used to verify the correctness of the obstacle avoidance algorithm, and few visual simulations are performed in the virtual ocean environment. After continuous research, it has been found that virtual reality technology can realize the algorithms that could not be realized before, and can also perform better human-computer interaction [2]. The AUV can avoid obstacles very flexibly during underwater navigation and can predict the navigation path in advance.
2. Visual simulation system for AUV obstacle avoidance of autonomous underwater vehicle in virtual environment

The figure shows the structure of the visual simulation system for AUV obstacle avoidance:

![Fig. 1 The structure of the visual simulation system for obstacle avoidance](image)

The main function of the forward-looking sonar in the visual simulation system for AUV obstacle avoidance is to detect the existence of obstacles on the navigation road. If an obstacle is found during the detection, the information about the obstacle can be extracted according to the message from the forward-looking sonar, and the exact position of the obstacle and the distance between the sailing vehicle and the obstacle can be obtained through analysis. The collision avoidance algorithm is to utilize the information from the forward-looking sonar to select an obstacle avoidance strategy, calculate the final result according to the algorithm, and input the result into the visual simulation system for AUV obstacle avoidance.

3. Development process of visual simulation for autonomous underwater vehicle in virtual environment

In the development of virtual visual simulation, it was necessary to make a simulation environment and a simulation driver. When making a simulation environment, it mainly included model design, scene construction, special effects design, etc. When designing a virtual simulation, the effect was required a three-dimensional model as realistic as possible, and the simulation drive mainly includes scene driving and model mobilization. The purpose of simulation driving was to be able to reproduce the simulation environment and operate in real time. The platforms of Multigen Creator and Vega software were used in design. Firstly, Multigen Creator was used for modeling, and then Vega software was utilized to build 3D scenes [3-4]. The AUV system was used to predict obstacles in advance in a complex virtual environment, and then a calculation program was applied to separate the calculated path from the actual path, so that the real-time synchronization can be implemented, to make sure the real-time display.

4. Establishment of virtual marine environment in virtual environment

When establishing a virtual marine environment, the following aspects were mainly established: AUV entities, obstacles in the sea, underwater marine environment, and submarine terrain, and the simulation model build 3D models mainly by Multigen Creator 3.0.

4.1. AUV modeling

The AUV model established is shown as the figure:

![Fig. 2 AUV model](image)
When building the AUV 3D model, it mainly required to establish 4 lateral auxiliary boosters, AUV head collision avoidance sonar, main push propeller, equipped functional sections, etc.

4.2. Modeling of submarine terrain in virtual environment
The terrain generation tool Creoto was used when modeling the submarine terrain. The data format needed to be converted first before the terrain was generated, then converted into DED files by DED tool, and then generate terrain files in flt format with Polymesh algorithm. Finally, the corresponding geographic feature data was pasted on the designated location. The actual submarine terrain could be restored after the completion of the entire step.

4.3. Simulation of virtual underwater marine environment
For the underwater marine environment, it mainly simulated the turbidity effect in seawater. The turbidity effect in normal seawater is caused by a lot of suspended particles, so some atomization effects could be added to restore when the ocean environment was simulated, which not only increased the sense of reality of the environment, but also reduced the distortion of geometry.

5. Collision avoidance algorithm for autonomous underwater vehicle in virtual environment
When performing the obstacle and collision avoidance algorithm in virtual environment, it was mainly divided into the following steps: First, the AUV forward-looking sonar was divided into three parts of the detection area, mainly including the right ahead, left front, and right front. In each area, the nearest distance between AUV and the obstacle was input. The three input distances were the distance information between AUV and the obstacle, and they can also represent the azimuth information. Then the AUV and azimuth information of the target were taken as another input result, and the combination of these input results could represent the overall environment information. Through the simulated collision detection information by the forward-looking sonar, it could be known that when the distance between the AUV and the obstacle was greater than 100, no obstacle was detected. If an obstacle was found during the detection, the accurate information about the point of impact and the length of the sonar line could be calculated. The length of the sonar line represented the distance between the AUV and the obstacle \[^{5-7}\]. The corresponding sonar line was divided into three areas, and the minimum distance of each area was taken for input. When the target was in front of the AUV, the target position was positive, otherwise it was negative; When the AUV turned right, the value of the yaw angle was positive, while when the AUV turned left, the value of the yaw angle was negative.

The turning principles of AUV were summarized as follows: If obstacles appeared to the left or right or in front of the AUV during detection, the AUV should turn right or left.

6. Simulation results of obstacle avoidance for autonomous underwater vehicle in virtual environment
The figure shows the state equation of the AUV direction system:

\[
\begin{bmatrix}
\beta \\
\omega_y \\
\psi
\end{bmatrix}
= \begin{bmatrix}
-1.3536 & 0.228 & 0 \\
11.742 & -5.381 & 0 \\
0 & 1 & 0
\end{bmatrix}
\begin{bmatrix}
\beta \\
\omega_y \\
\psi
\end{bmatrix}
+ \begin{bmatrix}
-0.113 \\
-1.883 \\
0
\end{bmatrix}\sigma'
\]

Fig. 3 State equation of the direction system

Where \(\beta\) represents the sideslip angle; \(\omega_y\) represents the yaw angular velocity; \(\psi\) represents the yaw angle; and \(\sigma\) represents the rudder angle input. The initial position of the AUV could be set as \((200, -100, -50)\), the target point position was set as \((150, 500, -50)\), and the state was set as \([0 0 0]\), that was, the initial heading was 0 °, and the speed was 10m / s. The simulation results are shown in Fig. 4:
The initial position of AUV

AUV detected the first obstacle and avoided it

AUV detected the second obstacle and avoided it

AUV avoided obstacles and sailed toward the target point.

Fig. 4 Simulation process

At the beginning of the simulation, the AUV navigation system first navigated according to the planned path, and set the corresponding target points and object obstacles when navigating. In the simulation, forward-looking sonar could be used to detect the existence of obstacles during navigation, and then implement obstacle avoidance. The figure shows the AUV trajectory and the tracking observation mode. Through simulation test, it was found that the forward-looking sonar could detect the existence of obstacles well and realize AUV obstacle avoidance.

7. Conclusions

Through the simulation test analysis, it could be seen that the collision vector simulation technology provided in the Vega visual simulation software platform could be used to successfully perform the simulation test, and then the corresponding visual simulation system was established according to the installed forward-looking sonar function, thereby realizing the obstacle avoidance of AUV in the virtual marine environment. It was found through simulation test that the currently established virtual obstacle avoidance system was very similar to the real environment, which was close to the actual situation both in visual effect and function, and could well simulate the underwater obstacle avoidance movement of the vehicle. In the whole simulation process, the collision avoidance algorithm can also play the largest role and really provide a certain reference for related vehicle obstacle avoidance.

References

[1] Sheryl Coombs, Paul Patton. Lateral line stimulation patterns and prey orienting behavior in the Lake-Michigan mottled sculpin (Cottus bairdi) [J]. Journal of Comparative Physiology, 2009, 195(3): 279-297.
[2] R. Weissert, C. von Campenhausen. Discrimination between stationary objects by the blind cave fish anoptichthys jordani (Characidae) [J]. Journal of Comparative Physiology, 1981, 143(3): 375-381.
[3] Wang Cheng, Zhou Junqing, Li Lijun. Creator visualization simulation modeling technology [M]. Wuhan: Huazhong University of Science and Technology Press, 2005.
[4] Wang Cheng, Zhou Junqing, Li Lijun. Vega real-time 3D visual simulation technology [M]. Wuhan: Huazhong University of Science and Technology Press, 2005.
[5] Gong Zhuorong. Vega programming [M]. Beijing: Defense Industry Press, 2002.
[6] Silence. fuzzy control principle and application [M]. Beijing: Mechanical Industry Press, 1999.
[7] Xu Demin. torpedo automatic control system [M]. Xi'an: Northwest Polytechnic University Press, 2001.