Research on Key Technology of Water Robot Avoiding Collision Based on Improved VFH Algorithm

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Abstract. For water robots in the intelligent operations meet to collision problems, a key collision avoidance algorithm based on VFH is developed, and the algorithm is improved and optimized, with a laser radar to launch the electromagnetic wave at a certain period Finally water robot controller was used to deal with data so as to analyze and process the data. Based on this, the histogram of obstacle vector field is established to judge the feasible and infeasible regions of the robot on water. Compared with the direction of the target destinations in feasible region corresponding weighting function is designed so as to determine the feasible area with smaller weight. the simulation by MATLAB to water robot position point for data analysis, Thus the simulation of water robot collision avoidance path diagram.

1. INTRODUCTION

With the continuous development of information technology and network communication technology, the degree of automation in various industries is constantly being improved, which has further triggered the "big data" "intelligence" and other upsurges. since the "Belt and Road" proposed, it has strengthened cooperation in various fields and regions, forming a key port at the sea, which requires continuous improvement of the intelligence of water robots, including the monitoring of the water environment by the water robot, and the safe cruise of the surrounding water area by the water robot. However, when the water robot encounters obstacles such as buoys and lighthouses in the water area during the operation, the autonomous collision avoidance cannot be realized well. Therefore, it will be of great significance to develop a kind of autonomous collision avoidance surface robot for the development of marine industry. At present, many ships use automatic identification system for collision avoidance, but the design of the system is mostly used for large ships. If the system is applied to small and medium-sized ships.it will cost a lot. The application of AIS to small ships will produce lower cost performance. For the current collision avoidance algorithms, genetic algorithms and ant colony algorithms. The disadvantage of genetic algorithm is that the algorithm is difficult to be realized by programming and cannot make use of the feedback information from the network in time, which leads to the slow speed of the algorithm; the disadvantage of ant colony algorithm is that the convergence speed of the algorithm is slow, It is easy to fall into local optimum. Therefore, when the above method is complex in the water area. The above algorithm is not suitable for the implementation of collision avoidance for the water robot, and the marine environment is complex, and it is the premise of the safe navigation of the
unmanned aerial vehicle on the water to be able to complete its own obstacle avoidance. The radar emits electromagnetic waves around in a certain period to measure the corresponding distance to establish the vector field histogram. In recent years, VFH algorithm has been widely applied to the major transportation industry through its advantages of simple algorithm and good collision avoidance effect. The VFH algorithm proposed by Qu pan and others for unmanned vehicle motion planning problem [1]; Zhou Jun et al. Proposed the improvement strategy of VFH algorithm based on memory matrix $A^*$ guidance domain [2]; Sun yang Zhi et al proposed VFH barrier algorithm combined with Kalman filter [3]; vector field histogram (VFH) was first used by Johann Borenstein to solve the problem that the machine is unmanned, but the VFH algorithm is mostly applied to UAVs and unmanned vehicles, However, there are few researchers on the complex water surface.

Therefore, in response to the complex environment on water and other issues, this paper proposes a key collision avoidance algorithm based on improved VFH, which can perceive the surrounding environment of the water robot through radar, and can obtain the dynamic information of the surrounding environment of the water robot in real time. Therefore, the water robot can realize automatic collision avoidance all the time, and the sea is complex. The ability to avoid obstacles is the premise of the navigation and the guarantee of the efficient completion of the task.

2. INTRODUCTION OF VFH ALGORITHM

Vector field histogram algorithm is abbreviated as VFH, which is literally translated as "vector field histogram algorithm". Algorithm to calculate the weights of marching in all directions. The more obstacles in this direction, the greater the weight. Kalman filter (KF) is a classic algorithm in the field of environmental modeling. Smith, self and Cheese man published a series of papers on KF from 1986 to 1999, The idea of CML is put forward [5]. VFH algorithm includes three main conditions.

Fig. 1. Angular resolution

Cartesian histogram grid: two-dimensional Cartesian histogram grid is composed of distance sensor of water robot.

Polar histogram: one dimensional polar histogram is constructed by reducing the Cartesian histogram around the instantaneous position of the water robot.

Candidate valleys are based on the proximity to the target direction to select consecutive sectors with a density of polar obstacles below the threshold.

Grid method decomposes the robot working environment into a series of grid cells with binary data. After the workspace is decomposed into cells, heuristic algorithm is used to search for safe paths in the cells. [6]

After the vector field histogram is established, an appropriate threshold is determined through experiments. Threat level of the sector is greater than the threshold value is higher, as the impassable area, the rest of the sector as a transit area [7]. Water robot with $360^\circ$ sent around a big cycle electromagnetic wave. In VFH algorithm, angle resolution should be determined, The range of radar scanning is divided into several sector areas, and the dynamic geographic position information of the water robot and the geographical position information of the target waypoint are obtained by GPS technology.

$$\text{sector} = \frac{360^\circ}{\text{angle resolution}}$$  \hspace{1cm} (1)
Fig. 2. Relative direction

The position coordinates of the ship are constantly changing, and the position of the target waypoint relative to the ship's direction is also constantly changing. VFH algorithm has the advantages of small amount of calculation and high real-time performance, which is suitable for the real-time obstacle avoidance planning of the water robot [8].

3. ANALYSIS OF COLLISION AVOIDANCE ALGORITHM
The key VFH algorithm water robot collision avoidance key research mainly determines the CV value of the grid and determine near the trough of the target area, to determine the final collision avoidance.

![Algorithm flow chart]

3.1. Determine the direction of the water robot
1) Determine the direction of the water robot.

\[ \text{start}_{\text{index}} = \frac{\text{goal}_{\text{sector}}}{\text{angle}_{\text{resolution}}} \] (2)
After the index of the target direction is determined, the water robot will drive in the direction of the target. At the same time, the radar will scan the surrounding environment in a certain period when the water robot is driving in the water area. Laser radar and ultrasonic sensors are commonly used in mobile robot navigation and positioning of distance sensor, and the principle is the same as that of ultrasonic ranging systems. If the buoy or lighthouse and other obstacles are encountered in the scanning process, the controller will receive the reflected signal from the radar, and finally determine the distance between the radar and the obstacle. Sometimes the obstacle has a certain width, at this time, the target direction is taken as the center index, and angle is used as the index. If resolution is the unit and 60 units are used as a group to cycle, the cycle body of each cycle is as follows:

\[
\text{index} = (\text{start_index} + i) \% \left(\frac{360}{\text{angle_resolution}}\right)
\]

\[
\text{scan_distance}_\text{min} \leq \text{ranges[real_index]} \leq \text{scan_distance}_\text{max}
\]

\[
\text{scan_distance} = \text{scan_distance}_{\text{max}} - \text{ranges[real_index]} + \text{scan_distance}
\]

According to the above formula, if the angular resolution angle is 1, each internal cycle will cycle 60 times. If 60 times of accumulation sum of obstacle distance, the external cycle will cycle for 12 times, then the radar scanning range will be divided into 12 small fan areas, and each small sector area will correspond to a scan_distance.

3.2. Determination of CV value

Scan is determined by the above. Distance, if \(\text{scan_distance} < a (0 < a < 0.5)\) indicates that there is no obstacle in the process of moving forward, and the driving direction remains unchanged_distance<a,

\[
\begin{align*}
\text{CV} &= 0 & \text{scan_distance} < a \\
\text{CV} &= 2 & a < \text{scan_distance} < 0.4 \\
\text{CV} &= 4 & \text{scan_distance} > 0.4
\end{align*}
\]

From the above, 12 fan-shaped areas correspond to one CV value. Therefore, two consecutive CV values of 0 are selected in the candidate direction, which can determine the driving direction of the water robot. Finally, the feasible area can be seen through the histogram, as shown in the figure below:

Fig. 4. CV value histogram

Determination of reliability CV value of improved algorithm

When the original algorithm determines the CV value, it does not consider the width of the water robot and the dynamic characteristics of the water robot. Therefore, when the water robot judges the possibility of obstacles, it will produce certain errors, which will affect the aquatic robot to carry out water work. Therefore, the method of determining the CV value of the original algorithm is improved according to the above:

\[
\text{cv} = C^2 * \left(a - b * (d^2)\right)
\]

\[
a = 1 + b * (d_{\text{max}})^2
\]

Where D is the distance between the underwater robot and the obstacle returned by radar, and C and B are constant. From the above formula, when the distance between the robot and the obstacle is getting closer and closer, the CV value will be larger and larger, so that n sectors can be determined by radar.
scanning once a week, \( n = \frac{360}{F} \), and each sector corresponds to a CV value, and then a threshold value is given. However, the CV value calculated according to the above formula is large, so that the left end of the trough is different from the right end of the trough by several sectors. In this way, considering the width of the water robot itself, the obstacles on the water surface can be avoided with great probability.

![Fig. 5. After the improvement of the algorithm, CV value histogram](image)

Through GPS information positioning technology, the target waypoint is read, and then the direction of the target waypoint relative to the water robot is calculated. The possibility of obstacles in this direction is judged by the weight. If the weight is less than \( a \), then the driving direction of the water robot remains unchanged. Otherwise, the driving direction of the water robot is determined by judging the CV value.

4. MATLAB SIMULATION

In this paper, based on the VFH algorithm, this algorithm is improved, so as to develop a kind of autonomous collision avoidance underwater robot. Before the improvement of VFH algorithm, if the width of obstacles is small, it can achieve autonomous collision avoidance. However, if the width of obstacles is large, the improved VFH algorithm is not improved, It is not conducive to the water robot to avoid collision.

![Fig. 6. Before the improvement of VFH algorithm](image)

Because of the improved VFH algorithm, the difference between the CV value and the threshold value is large, and the left end of the trough and the right end of the trough contain more sectors, which is conducive to the water robot in the collision avoidance operation, when encountering a wide range of obstacles, it can carry out collision avoidance operation in a large range.
Fig. 7. After the improvement of VFH algorithm

It can be seen from the above figure that the improved VFH algorithm will not be affected by the size of the obstacles when carrying out collision avoidance operation. If the buoy, lighthouse and other obstacles are encountered on the way, it will deviate from the original route, but will eventually return to the direction of the preset route, so as to achieve the effect of autonomous collision avoidance.

5. CONCLUSION

Based on the simplicity of the VFH algorithm, this paper can better use C, MATLAB and other languages to implement this algorithm. On the basis of the original algorithm, the weight function is improved, and the CV value is finally obtained. After the improvement and optimization of the algorithm, when the underwater robot implements collision avoidance, it can finally determine the best collision avoidance direction according to the size of the underwater robot itself, the size of the obstacle, and the optimized CV value. The research and development of the algorithm lays a certain foundation for the future development of unmanned ship and navigation. When the underwater robot is working, it can effectively reduce the collision and greatly improve the working efficiency of the underwater robot.

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