ISSN: 2414-1895 DOI: 10.6919/ICJE.202102_7(2).0051

Unmanned Ship Real-Time Collision Avoidance Algorithm based on Artificial Potential Field Method

Shuai Sun

School of Navigation and Naval Architecture, Dalian Ocean University, Dalian 116023, China.

568522213@qq.com

Abstract

With the rapid development of various technologies of unmanned autonomous platforms, research on highly autonomously controlled unmanned ships is a new goal of the shipbuilding and shipping industry. It is of great research significance to improve real-time collision avoidance during unmanned ship navigation. The artificial potential field method is a more mature and efficient algorithm in the real-time collision avoidance algorithm, which allows the moving object to avoid the obstacle while taking into account the moving performance of the moving object. Therefore, it is widely used in real-time obstacle avoidance for mobile robots. For the real-time collision avoidance algorithm of unmanned ships, this paper builds on the gravitational field and repulsive field based on the artificial potential field method. The target point is attractive to the unmanned boat, and the obstacle has repulsive force to the unmanned boat. The unmanned boat moves under the effect of the combined force and keeps approaching the target point. Simulation results show that the unmanned ship real-time collision avoidance algorithm based on artificial potential field method enables the unmanned ship to avoid obstacles quickly and reach the target point.

Keywords

Unmanned Ship; Real-Time Collision Avoidance; Collision Avoidance Algorithm; Artificial Potential Field Method.

1. Introduction

With the continuous progress of science and technology, the technological development level of ships has also been continuously improved, and it has developed toward large-scale, professional, high-speed and unmanned. In particular, the rapid development of high-tech technologies such as artificial intelligence, Internet of Things, and big data in the field of ships and marine engineering has made the research of smart ships and unmanned ships attracted the attention of countries all over the world.

Ship navigation safety mainly depends on the experience and immediate judgment of the pilot, as well as various navigation facilities such as radar, automatic identification system (AIS), automatic radar plotter (ARPA) as auxiliary equipment, providing maritime information for ship operators Adopt ship collision avoidance strategy. Since the 1970s, ship collision avoidance has been widely concerned, and its related research has also been promoted to a certain extent, but there are still many problems that need to be solved. Therefore, research on intelligent real-time collision avoidance algorithms is of research significance for reducing human errors in accidents, reducing the growth of professional training in the field of navigation, and even developing into a fully automatic, unmanned and highly intelligent navigation system [1].

At present, the research on the global obstacle avoidance algorithm for unmanned ships has reached a relatively perfect point. There are several types of global obstacle avoidance algorithms: grid

ISSN: 2414-1895 DOI: 10.6919/ICJE.202102_7(2).0051

method, ant colony algorithm, A algorithm, etc[2]. However, in real-time obstacle avoidance, unmanned ships often work in partially unknown or completely unknown environments, and need to continuously detect the surrounding environment through sensors. According to the data detected by the sensors: the distance between the obstacle and the unmanned ship itself, The size, shape, etc., constantly adjust their position, speed, direction, and require the unmanned boat to adapt randomly. This obstacle avoidance method requires the performance of the unmanned boat's own sensor to be very powerful, and the designed algorithm should be more and more accurate and practical. The current real-time obstacle avoidance algorithms are as follows: neural network algorithm, fuzzy logic algorithm, artificial potential field method, genetic algorithm, etc. However, the artificial potential field method has the advantages of simple mathematical calculation, easy to understand the principle and easy to program, so this paper uses the artificial potential field method to realize the real-time obstacle avoidance of unmanned ships.

2. Artificial potential field method

2.1 Principle description

In 1986, Oussama Khatib first proposed the concept of artificial potential field method (Artificial Potential Field). The core idea of artificial potential field method is to imagine the motion of an object as a motion in an abstract combined potential field [3-4]. Imagine countless fields of gravity and repulsion in the motion environment of an object, making the object move in a space similar to a "magnetic field", the force generated by the target point on the object attracts the object like a "magnet" , Think of it as gravity, and the force of the obstacle and the object is like the force between the same pole of the magnet, think of it as a repulsive force, the object moves under the combined force of this gravitation and repulsion, every time you walk to One position is to calculate the magnitude and direction of the resultant force on the object at the current position, and to detect the surrounding environmental information while walking. This method proposes to combine the obstacle avoidance planning problem of the object with algebraic problems and geometric problems. It makes the abstract things concrete, which is convenient for expert research and academic analysis, and has made great contributions to the planning and research work of real-time obstacle avoidance.

The virtualized gravitational field and repulsive field are represented by Uatt and Urep respectively. Using the way of thinking to solve the vector problem in mathematics, calculate the magnitude and direction of the gravitational and repulsive force on the object by calculating the negative gradient of the gravitational field and the repulsive field, The object moves to the target point under the effect of the resultant force.

2.2 Potential field function of artificial potential field method

(1) The commonly used gravitation function of artificial potential field method can be expressed as:

$$U_{att}(q)=\frac{1}{2}\xi\rho^{2}\left(q,q_{goal}\right) \tag{1}$$

Among them, ξ represents the gravity scale factor, which is a constant; $\rho\left(q,q_{goal}\right)$ represents the distance between the current position of the object and the target point.

(2) Unlike the gravitational field, the traditional repulsive field function is a piecewise function, which can be expressed as:

$$U_{rep}(q)=\begin{cases}\frac{1}{2}\eta(\frac{1}{\rho\left(q,q_{obs}\right)}-\frac{1}{\rho_{0}})^{2} & \rho\left(q,q_{obs}\right)\le\rho_{0}\\ 0 & \rho\left(q,q_{obs}\right)>\rho_{0}\end{cases} \tag{2}$$

Among them, η represents the repulsion scale factor, which is a constant; $\rho\left(q,q_{obs}\right)$ represents the distance between the current position of the object and the obstacle; ρ_0 represents the radius of influence of the obstacle.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202102_7(2).0051

3. Realization of real-time collision avoidance algorithm for unmanned ship

3.1 Obstacle chart construction

A chart is a resource that describes maritime traffic information and provides necessary reference data for nautical ships. On the chart, the water depth, the shape of the coast, reefs, islands, offshore structures, beacons, waterways, etc., are detailed enough information that may affect the safety of the ship. Nowadays, electronic charts are widely used due to the advantages of easy integration of the rest of the information [5]. For the real-time collision avoidance requirement of artificial potential field method, the information of electronic chart is enough. Therefore, in this section, based on the chart of a certain sea area, through the binarization processing of the chart, the obstacle information is extracted to construct the obstacle chart.

Fig. 1 Nautical chart

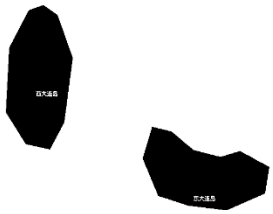

Fig. 2 Obstacle chart

3.2 Simulation experiment

In order to verify the real-time obstacle avoidance effect based on artificial potential field method, the simulation of obstacle avoidance process is realized by using MATIAB programming. In the experiment, the obstacle chart grid is defined as 1mx1m, and the repulsion field and the gravitational field are set respectively for the obstacle and the target point. The scale factor of gravitational field is $\zeta = 3$, the scale factor of repulsive field is $\eta = 5$, and the influence range is $\rho = 5$m. The starting point coordinate of the test boat is set to (50,50), the target point coordinate is set to (270,730), and the capture radius R = 3M. The length of the ship is L = 20 m, the width of the ship is w = 10 m, the bow angle is 15°, the maximum speed of the unmanned ship is v = 10 m/s, and the maximum turning angle is $\theta = 45°$. The simulation results are as follows:

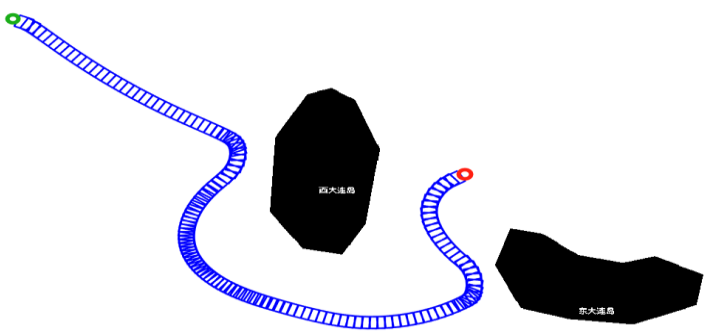

Fig. 3 The simulation diagram

ISSN: 2414-1895 DOI: 10.6919/ICJE.202102_7(2).0051

4. Conclusions

According to the analysis of simulation experiment results, the real-time obstacle avoidance method of the unmanned ship based on the artificial potential field method can avoid obstacles quickly and stably, and reach the set target point. When modeling the environment, the navigable environment of the unmanned ship is fully considered, and the chart is used as the base chart to construct the obstacle chart. When setting the input parameters of the algorithm, the structure and motion characteristics of the unmanned ship are considered, and the maximum speed and steering angle are set so that the simulation result is more in line with the motion characteristics of the actual unmanned ship.

Acknowledgments

This work was financially supported by Liaoning Provincial Education Department's 2019 Scientific Research Funding Project (QL201911).

References

[1] Kim D,Hirayama K,Okimoto T.Ship Collision Avoidance by Distributed Tabu Search.TransNav,the International Journal on Marine Navigation and Safety of Sea Transportation, 2015,9(1):23-29.

[2] Ahmed F, Deb K. Multi-objective optimal path planning using elitist nondominated sorting genetic algorithms [J]. Soft Comput. 2013, 17(7):1283-1299.

[3] Yan R, Pang S, Sun H, et al.Development and missions of unmanned surface vehicle.Journal of Marine Science and Application, 2010, 9(4):451-457.

[4] Damen Shtay A, Gharib W. An Intelligent Control System for Ship Collision Avoidance.International Journal of Engineering & Technology, 2012, 9(10):26-31.

[5] Tsou M. Multi-target collision avoidance route planning under an ECDIS framework.Ocean Engineering, 2016, 121:268-278.