ISSN: 2414-1895 DOI: 10.6919/ICJE.202012_6(12).0012

Research on Path Planning based on Unmanned Ship

Wenbo Yuan

Shanghai Maritime University, Shanghai 201306, China.

630432808@qq.com

Abstract

In order to better cope with the complicated maritime situation, conduct maritime missions under the premise of ensuring the safety of maritime scientific research personnel and face unknown risks. Surface Unmanned Ship (Surface Unmanned Ship) came into being. The continuous deepening of maritime missions by various countries has also put forward higher requirements for the intelligent of unmanned ships. In recent years, the Internet of Things, cloud computing, big data, artificial intelligence and other new concepts and the enrichment of new technologies have enabled unmanned ships to better complete complex waterborne tasks. Therefore, the realization of safe obstacle avoidance based on overall and local path planning of unmanned ships has become the research focus of unmanned ship technology at this stage. Scholars from various countries have conducted research on the path planning and safe obstacle avoidance of unmanned ships, and proposed many methods to realize path planning. In the face of the requirements of timeliness and accuracy of path planning, this article summarizes the proposed methods, as well as the improvement and optimization methods, and hopes to provide inspiration for the next research direction.

Keywords

Path planning; Unmanned surface vessel; Safe obstacle avoidance; Optimization algorithm; Current situation.

1. Introduction

With the rapid development of world science and technology, the development and survey of new energy have also received sufficient attention, and as the ocean known as the "human treasure house", it has become the center of development of all countries. Abundant marine resources drive mankind to succeed. However, sea surface weather is changing rapidly, full of uncertainties and dangerous factors, which seriously affects the personal safety of marine personnel on the sea surface, and seriously affects normal navigation, scientific research, and exploration tasks. Unmanned surface ships, as an intelligent product of emerging technology, have gradually replaced the traditional "ship + manual" mode in some maritime tasks with their outstanding advantages such as low risk, small size, fast speed, and simple operation. With the increasing importance of surface unmanned ships, path planning for unmanned ships has become an important research content.

The research content of unmanned ship path planning is to plan a reasonable, safe, collision-free optimal path with low cost and short voyage under a given environment. At present, most scholars' research on the path planning of unmanned ships is concentrated in the field of robots and unmanned aerial vehicles. The more common path planning algorithms are mainly the following: A* algorithm, Dijkstra algorithm, simulated annealing algorithm, artificial potential energy method, genetic algorithm, ant colony algorithm, etc. Similarly, some scholars put forward new concepts and new ideas based on the above-mentioned mainstream algorithms based on timeliness, accuracy and other influencing factors, combined with experience.

ISSN: 2414-1895
DOI: 10.6919/ICJE.202012_6(12).0012

2. Based on the artificial potential field method

The artificial potential field method is a concept proposed by Professor Khatib in 1986. It is a method of expressing human thinking by using the epistemological principles of physics. The central idea is to regard the movement of unmanned surface ships in space as a process of force movement in a virtual potential field. The gravitational field constructed by the target position produces attraction to the unmanned ship, and the repulsive force field constructed by each obstacle position in the path produces repulsive force to the unmanned ship. The unmanned ship is in this virtual potential field, based on the combined action of the two forces. Down, move towards the target point to form a safe path without collision.

The movement principle of the traditional artificial potential energy method model is to put the unmanned ship into the virtual potential field. During the movement, the repulsion field increases with the approach of the unmanned ship and the obstacle; the gravitational field follows the unmanned ship and the preset the distance from the target point is enhanced. In this way, it can not only ensure the unmanned ship's continuous tracking of the target point, but also avoid the influence of obstacles on the way and realize obstacle avoidance. Therefore, the key to the artificial potential field method is the construction of the gravitational potential field function and the repulsive potential field function.

The gravitational potential field function is the concept of distance, which is related to the position of the preset target point. Assuming that X_c represents the coordinates of any position of the unmanned ship in the process of motion, and X_g represents the position coordinates of the target point, the gravitational potential field function is:

$$U_{att}(X) = \frac{1}{2} \cdot K_{att} \cdot \rho^2(X_c \cdot X_g) \tag{1}$$

In the above formula, $U_{att}(X)$represents the gravitational field gain constant, $\rho(Xc \cdot Xg)$ expresses the actual distance from the unmanned ship's coordinates to the preset target point coordinates, and the direction of the gravitational field is the unmanned ship points to the target point. Therefore, the gravitational force can be obtained by calculating the negative gradient of the gravitational potential field function:

$$F_a = -\nabla U_{att}(X) \tag{2}$$

The repulsive potential field function is also related to distance, corresponding to the target point of the gravitational field, and the repulsive potential field function is related to the position of the obstacle. Under the same assumption that X_c is the coordinate of any position during the movement of the unmanned ship, X_0 Expressed as the coordinate position of the obstacle, the repulsive potential field function is:

$$U_{rep}(X) = \begin{cases} \frac{1}{2} K_{rep} \left[\frac{1}{\rho(X_c, X_0)} - \frac{1}{\rho_0}\right]^2 & , \ \rho(X_c, X_0) \le \rho_0 \\ 0 & , \ \rho(X_c, X_0) \ge \rho_0 \end{cases} \tag{3}$$

In the above formula, K_{rep} is expressed as the repulsive force field gain constant, $\rho(X_c, X_0)$ is expressed as the actual distance from the coordinates of the unmanned ship to the coordinates of the obstacle, and ρ_0 is expressed as the obstacle itself Effective influence distance: When $\rho(X_c, X_0) \le \rho_0$ obstacles will repel the unmanned ship, to avoid the unmanned ship from colliding with the obstacle when it is sailing, the direction of the repulsive force field is from the obstacle to unmanned ship, the negative gradient of the potential field function of the repulsion can be calculated as:

$$F_r = -\nabla U_{rep}(X) \tag{4}$$

For the overall artificial potential field model, it is the force field generated by the corresponding algorithm in the vicinity of the gravitational field and the repulsion field. Under the combined action, the artificial potential field is defined as:

ISSN: 2414-1895 DOI: 10.6919/ICJE.202012_6(12).0012

$$U(X) = U_{att}(X) + U_{rep}(X) \quad (5)$$

Similarly, according to the space dynamics equation and Lagrangian equation, the force F of the artificial potential field on the unmanned ship can be derived, which can be defined as:

$$F(X) = F_{att}(X) + F_{rep}(X) \quad (6)$$

In summary, the artificial potential field method as a model is simple and clear, the algorithm structure is clear, and the calculation is simple, easy to express, and the algorithm has strong practicability. The path obtained is relatively smooth and safe. While its advantages are outstanding, it also exposes many problems. The problems of local minima and unreachable goals have always been the problems to be solved in the application of artificial potential field algorithm in the path planning and obstacle avoidance of unmanned ships: 1. First, when an obstacle exists on the straight line between the current position of the unmanned ship and the position of the target point, the unmanned ship's gravitational force at the target point continues to decrease and the repulsive force of the target point continues to increase due to the continuous approach of the obstacle. When it advances to a certain point, the repulsive force and gravitational force are balanced, and without any other external force, the unmanned ship will stand still and cannot reach the target point; 2. When the target point exists within the influence range of the obstacle, the gravity of the target point received by the unmanned ship in the process of approaching the target point continues to decrease and approach zero, while still being sustained by the repulsive force of the obstacle Effect, causing the unmanned ship to be unable to reach the target point; 3. When the unmanned ship passes through a place with dense obstacles during its movement, the repulsive force of the unmanned ship will exceed the attraction of the target point. This situation will prevent the unmanned ship from finding a suitable path. Falling into the risk of a local minimum, and thus unable to accurately reach the target point, etc.

In view of the above-mentioned local minimum and the typical problems that the target point cannot be reached by the artificial potential field method, experts and scholars from various countries have also focused on and put forward many improved ideas and methods:

Document [1] proposed to improve the potential field function. Based on a single influencing factor, distance and gain constant, it was proposed to increase the relative distance and relative speed between the unmanned ship and the target point, while increasing the unmanned ship and Obstacles' relative speed, acceleration and other data are used as constraints to make the potential field function more multi-dimensional, thereby effectively solving the dilemma of falling into local optimal and unreachable, but this method also has low parameter accuracy and long response time. This problem needs to be improved continuously.

Literature [2] proposed the idea of using an exponential function to replace the potential field function. After the replacement, the intensity of the potential field will be suppressed. At the same time, the "relative position between the unmanned ship and the target point" is added to the repulsive potential field function. An impact factor is used to solve the problem of unreachable targets; and for the problem of unmanned ships falling into local minimums, two judgment conditions are introduced. By judging whether the unmanned ships are trapped, the corresponding potential field gain coefficient is selected, So that the unmanned ship can jump out of the dilemma of local minimum.

Literature [3] firstly introduced the DE algorithm into the potential field model at the model level, proposed the potential field path evaluation equation and the improved version of the potential field model based on the evolution mechanism, so as to achieve the preliminary optimization of the potential field path; At the path point level, the motion constraint condition of "maximum steering angle" is added, which enables the algorithm to perform secondary optimization on the local path, effectively improving the navigation efficiency of the unmanned vessel, and solving the problems of local minimum and inaccessibility.

Literature [4] is also an improved idea of the artificial potential field method. Its core content is to increase the relative velocity and relative acceleration. At the same time, the improved algorithm mentions the "linear potential field". The path creates a virtual field for the unmanned ship. Its

ISSN: 2414-1895 DOI: 10.6919/ICJE.202012_6(12).0012

function is to provide an additional attraction after the unmanned ship avoids obstacles. It is used for the unmanned ship to continue to move forward, through the organic planning of the local and global planning. Solve the problem uniformly.

The core idea of the literature [5] is to introduce the relative position of the unmanned ship and the target point into the gravitational potential field model, and at the same time introduce the relative motion speed of the unmanned ship (robot), obstacles and target point as influencing factors into the repulsion. In the potential field model, a new potential field function can be reconstructed. The obstacle connection method is used to process environmental information, which can effectively reduce the complexity of calculation. A method including the establishment of local target points and repulsion decomposition optimization is proposed to solve the local minimum problem of the artificial potential field method.

While optimizing the single artificial potential field method, another group of scholars focused on solving the typical problems of a single algorithm by using a combination of multiple algorithms. In the path planning of multi-algorithm combination, it not only retains the advantages of the simple principle and rapid response of the artificial potential field method, but also overcomes the shortcomings of the single artificial potential field algorithm to a certain extent, and provides a way for path planning and obstacle avoidance. New ideas and new ideas.

Among them, the literature [6] proposed an improved artificial potential field-ant colony algorithm combination form. The important core of the algorithm is to improve the update rules and the heuristic information function. On this basis, the maximum and minimum ant colony system is introduced, which greatly improves the search efficiency and reduces the search scope as much as possible; in addition, in the heuristic information function The control factors of the artificial potential field method are increased, and at the same time, the blindness problem that may exist in the traditional ant colony algorithm in the initial search period is effectively reduced, thereby speeding up the convergence speed of the algorithm and further improving the efficiency of the algorithm.

Literature [7] also proposed a potential field ant colony algorithm, that is, in the initial iteration of the basic ant colony algorithm, the artificial potential field method is used to influence the pheromone quantity of ants, thereby improving the efficiency of finding the optimal path. Compared with the traditional ant colony algorithm, this algorithm can effectively improve the efficiency and convergence of global path planning, and provides a reliable iterative algorithm design basis for the realization of mobile robot environment modeling and motion strategy planning. The path planning of law provides new ideas.

Literature [8] proposed a path planning algorithm combining artificial potential field method with improved repulsion and fuzzy algorithm. Firstly, the logarithmic function of the Euclidean distance between the robot and the target point is introduced into the repulsion field model to form a new artificial potential field. At the same time, the criterion formula for the position coordinates of robots, obstacles and target points is added. The angle difference and the resultant difference between the gravitational and repulsive forces in the artificial potential field are respectively set as fuzzy inputs. After testing, it can be proved that this algorithm can solve the problems of local optimization and unreachable target points in the traditional artificial potential field method, reduce the amplitude of path trajectory fluctuations, and no wandering in concave groove obstacles.

3. Based on A* algorithm

The A* algorithm is a new algorithm proposed in 1969. It has received widespread attention because its computational efficiency is higher than the mainstream dijkstra algorithm at the time. When it is used in path planning, it also reflects a high degree of completion far exceeding other algorithms; Afterwards, many scholars also conducted more in-depth research on the A* algorithm, and put forward some improvement ideas and ideas, and achieved good results.

The traditional A* algorithm is a typical heuristic search algorithm. Heuristic search avoids invalid search paths to a certain extent, thereby improving search efficiency. This algorithm relies on its

ISSN: 2414-1895 DOI: 10.6919/ICJE.202012_6(12).0012

depth-first, breadth-first, and best-first Outstanding advantages have been widely used. The evaluation function of the A* algorithm at a certain node can be expressed as:

$$f(n) = g(n) + h(n) \tag{7}$$

Among them, $f(n)$ is the evaluation function of node n from the initial point to the target point; $g(n)$ is the actual cost from the node to the nth node in the state space, and $h(n)$ is the estimated cost of the best path from n node to the target node, In the formula, when the proportion of $g(n)$ in $f(n)$ is higher, the search tends to a horizontal trend; and when $g(n) = 0$, it means to find the target node without considering the cost. In the simultaneous formula, the higher the proportion of $h(n)$ in $f(n)$, the more emphasis is placed on the influence of heuristic factors on search efficiency, and the more search tends to the vertical trend; The smaller the $h(n)$ proportion, the more prominent the characteristics of horizontal search;; and when $h(n) = 0$, it is expressed as breadth first search.

The idea proposed in [9] is to solve the problem that the traditional A* algorithm cannot quickly return to the preset route after avoiding obstacles in path planning. It is proposed that a new generation value is added to the original cost function to improve A* algorithm; As a result, the unmanned ship can quickly return to the preset route after avoiding obstacles, and at the same time, to a certain extent, reduce the course deviation caused by the unmanned ship's active obstacle avoidance, and further ensure the efficiency and safety of the route.

The concept proposed in [10] is to solve the problem that the traditional A* algorithm is not smooth in path planning and is prone to local optimal solutions. An improved strategy is proposed. This algorithm is used in the rasterized two-dimensional environment model. Expand the node search neighborhood to 24 and 48 neighborhoods in, so as to obtain the global optimal solution in a larger optimization space and make the path smoother.

4. Based on ant colony algorithm

The ant colony algorithm is a probabilistic algorithm for finding optimal paths. The algorithm was a concept proposed by Dr. Marco Dorigo in his thesis in 1992. Inspired by the behavior of ants finding paths in searching for food, in the process of studying ants foraging, it was found that the behavior of a single ant was relatively single, while the overall behavior of the entire ant colony was more intelligent and efficient. After research, it is found that its overall thought is equivalent to taking the different routes traversed by the ants as different feasible solutions, and taking all the routes traversed by the ants as all feasible solutions in this situation. And each ant will leave pheromone on the path it travels. Ants with a short route will release more pheromone. Then, as time goes by, iterate continuously, and the accumulated pheromone on the short path will become more and more. If more, more ants will choose this path, forming a mechanism similar to positive feedback [11], Finally, all the ants will concentrate on the path with the strongest pheromone, which is the shortest path. This is the optimal solution for path planning.

In [12], aiming at the problems of slower convergence speed and premature maturity of ant colony algorithm, heuristic information based on the principle of unlimited step length is adopted, and the coefficients are dynamically adjusted to expand the search range, so that the results accelerate the convergence toward the shortest path.

Literature [13] proposed an improved ant colony algorithm for planning ship routes. By improving the pheromone update mechanism, the optimization strategy of the ant colony algorithm was strengthened, and the objective function was added to each iteration of the traditional ant colony algorithm. The best quality corresponds to the amount of pheromone on the path, and the comparison and at the same time weakens the amount of pheromone with the worst value, so as to design a shortest route for the ship.

The improved ant colony algorithm proposed in [14] can optimize the unmanned ship's trajectory in a shorter time. Compared with the traditional ant colony algorithm, the improved ant colony algorithm first takes into account the changes in the speed of the unmanned lifeboat during navigation. At the

ISSN: 2414-1895
DOI: 10.6919/ICJE.202012_6(12).0012

same time, taking time as the objective function, the optimization is carried out in the direction of shorter time, which can effectively improve the optimization path of the unmanned ship, and the navigation time is significantly reduced, which has better practicability.

5. Conclusion

Aiming at the path planning problem of unmanned ships, this article summarizes the research results of scholars from various countries on the above-mentioned traditional mainstream algorithms and algorithm optimization based on mainstream path planning algorithms such as artificial potential field method, ant colony algorithm and A* algorithm. Covers new ideas in the research of unmanned ship path planning. In general, the mainstream algorithms are summarized and summarized, and they are optimized and improved for the problems of timeliness and accuracy, and make certain contributions to future unmanned ship path planning problems. However, there are still many shortcomings in this article, and I hope it can be improved and perfected in the future study and research.

References

[1] Shan Chen,Peiguang Wang,Xiaoping Zong. Research on Dynamic Obstacle Avoidance Based on Improved Artificial Potential Field Method[J]. ELECTRONICS WORLD,2017(22):17-19.

[2] Kun Liu, Yonghui Zhang, Jia Ren. Path Planning Algorithm for Unmanned Surface Vehicle Based on an Improved Artificial Potential Field Method[J]. NATURAL SCIENCE JOURNAL OF HAINAN UNIVERSITY, 2016, 34(2):99-104.

[3] Zhuo Chen, Yunsheng Mao, Lifei Song, Zaopeng Dong, Xin Yang, Xinnan Fang. Path Planning Algorithm of USV Based on Evolutionary Potential Field Model[J]. Journal of Wuhan University of Technology (Transportation Science & Engineering), 2019,43(1):113-117,124.

[4] Fei Xue. Research on path planning and obstacle avoidance based on unmanned ship[D]. Harbin: Harbin Engineering University,2017.

[5] Cheng Chen. Unmanned Boad Path Planning Based on Improved Grid Method and Artificial Potential Field Method[D]. Zhenjiang: Jiangsu University of Science and Technology,2018.

[6] Kun Liu.The Path Planning of Unmanned Surface Vehicle Based on Artificial Potential Field and Ant Colony Algorithm[D]. Haikou: Hainan Univeristy,2016.

[7] Yuqing Chen,Tongxun Li,Shuanghe Yu,Zhipeng Shen. Global Path Planning of Robots Based on Potential Field Ant Colony Algorithm[J].Journal of Dalian University of Technology,2019,59(3):316-322.

[8] Sixin Wang,Gongquan Tan,Yufeng Luo,Shi Fan.Research on Path Planning Algorithm Based on Improved Artificial Potential Field-fuzzy Algorithm[J].Journal of Sichuan University of Science & Engineering (Natural Science Edition),2019,32(5):42-48.

[9] Bixiu Yu,Xiumin Chu,Chenguang Liu,Hao Zhang,Qingzhou Mao.A Path Planning Method for Unmanned Waterway Survey Ships Based on Improved A* Algorithm[J].Geomatics and Information Science of Wuhan University, 2019, 44(8):1258-1264.

[10] Feng Gao, Hao Zhou, Zhuoyu Yang. Global path planning of surface unmanned ship based on improved A* algorithm[J]. Computer Application Technology, 2020,37:120-125.

[11] Zhihui Xiong.Hardware/Software Partitioning Based on Dynamic Combination of Genetic Algorithm and Ant Algorithm[J]. Journal of Software,2005,16(4):503-512.

[12] KHALED AKKA,Farid Khaber.Mobile robot path planning using an improved ant colony optimization [J]. International Journal of Advanced Robotic Systems,2018,15(3): 1-7.

[13] Ying Wang,Weiting Liu. Path Planning of Ships Based on Improved Ant Colony Algorithm[J]. Modern Electronics Technique,2010,33(21):186-188.

[14] Chen Qiu,Haifeng Zhou,Rongjie Wang,Zhonghua Lin.Track Planning of Unmanned Lifeboat Based on Improved Ant Colony Algorithm[J]. Journal of Jimei University(Natural Science),2019,24(5):358-363.