Research on Decision Optimization Method of Avoiding Collision of Inland Ships Based on Intelligent Calculation

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Abstract. Shipping is one of the main modes of transportation, and the safety of ship operation is very important. The navigation conditions of the inland river are complex. The width of the river, the density of the ships and the height of the bridge all affect the navigation of the ships to a certain extent. Based on this, this paper proposes a decision-making optimization method for collision avoidance of inland ships based on intelligent calculation. By analyzing the process of ship collision, the genetic algorithm in intelligent calculation is used to avoid collision. The simulation results show that the best collision avoidance effect is achieved in the collision avoidance of the two ships and the collision avoidance of the ship and the bridge, which reduces the risk to the lowest level.

1. Introduction
Nowadays, shipping is very developed. The transportation of goods through ships has become an important means of transportation, thus promoting the development of economy [1]. At the same time, in the inland waterway, the number of ships is increasing, and the density of the ships going back and forth is as high as that of the cars on the road [2]. In addition, most of the inland rivers are very curved and complex. Under the dual influence of the increasing number of ships and the complexity of river hydrology, ship navigation accidents occur frequently, which poses a serious threat to people’s life and property safety [3]. Therefore, how to avoid collision of inland ships has become the focus of research.
In the aspect of ship collision, there are many experts and scholars who have made great achievements. In [4], the author points out that the traditional distance to approach point and the time to approach point are not enough to estimate the risk of collision and avoid action. The author proposes the collision risk parameter based on domain to avoid collision. In [5], by taking dynamic factors into account, the author designs a dynamic ship collision model, which uses the number of ship collision conflicts instead of the number of potential collision ships, and proposes an open water ship collision frequency model. In [6], the author uses the ten-year ship collision accident data from Fujian sea area to establish an ordered probability model to evaluate the factors that affect the severity of the collision.
between the two ships. It is found that poor visibility and night time are likely to be the factors that cause the severity of the collision. The above research has some progress in ship collision, but there are some disadvantages in the decision-making of avoiding collision, such as long time consuming and low accuracy. The emergence of intelligent computing provides a choice for solving related problems. The results show that the method is effective to solve the high-order stiffness problem with boundary conditions. In [8], the author uses the intelligent calculation to analyze the MHD flow on the model of extensible turntable. The scheme includes an effective neural network modeling capability, combining with the comprehensive optimization strength of genetic algorithm and interior point method, and has good robustness and stability. In [9], the author analyzed the plating kinetics of Oldroyd-8 constant fluid by intelligent calculation method, realized rapid convergence and improved accuracy. In [10], the author uses intelligent computing to analyze the trading behavior and change trend of financial market. Through the physical trend of quantitative and technical analysis of market overview theory to explain the transaction behavior in the financial market, it is proved that the financial transaction market follows a certain transaction logic. In conclusion, intelligent computing has the characteristics of short computing time and high accuracy. Therefore, the application of intelligent computing to the decision-making optimization method for collision avoidance of inland ships is considered.

Aiming at the problem of slow decision-making and prone to accidents in collision avoidance, this paper puts forward the decision-making optimization method for collision avoidance of inland ships based on intelligent calculation, and establishes the decision-making optimization method for collision avoidance, in order to provide reference for the safe and stable operation of shipping.

2. Methods

2.1. Overview of river ship collision
The ship domain refers to the surrounding waters of a ship. The shape of the ship field is generally elliptical, and the transverse distance in front of the ship is larger than that in the back. A larger area than the ship field is called the "dynamic boundary". When the obstruction has not reached the position of the ship field, the master will take measures to avoid collision. At this time, the distance between the obstruction and the ship field will be greater than that of the ship field, which is the "dynamic boundary". There is a minimum safety distance in collision, which refers to the distance between the latest operation point and obstacles when the ship is avoiding collision. Obstacles also include other ships that pose a threat. Once it is less than this safe distance, no matter what measures are taken, collision cannot be avoided.

2.2. Collision formation process
According to the ship field and the minimum safe distance, this paper divides ship collision into four stages as follows:
(1) No danger stage
When the inter phase distance between ships is farther than the boundary of ship field, there is no collision risk between the two ships. Even if the two ships go in opposite directions, as long as they are handled properly, the probability of collision is very low. Therefore, this stage is called non dangerous stage.
(2) Formation of collision risk stage
When the obstacles enter the ship field, the collision risk begins to form. At this time, the captain should adjust the speed and direction of the ship according to the surrounding conditions, so as to minimize the intrusion of obstacles and minimize the risk. At this stage, it starts from the barrier to approach the minimum safe distance.
(3) Forming an urgent dangerous stage
If the captain does not take measures to avoid collision in time, he will break through the minimum safety distance. When the objects intrude into the boundary of the minimum ship domain, they begin to form an urgent danger. If a ship encounters a vessel that can change direction and speed, it is likely
to solve the emergency situation; if it encounters a fixed obstacle such as a reef, it is unlikely to get rid of the emergency situation. After all, at this time, the distance between the ship and the obstruction is less than the latest point of full rudder avoidance, so it is difficult for the captain to avoid the obstruction no matter how he operates.

(4) Collision phase
When the ship is too close to the obstruction, and cannot get rid of the urgent dangerous situation, the ship immediately collides.

2.3. Optimization of collision avoidance model
The main influencing factor in river ship collision is the minimum safety area. Safety and economy should be considered in collision optimization. To minimize the risk of collision avoidance, the following functions are met:

$$\min_{i=1}^{m} \{\max_{j=1}^{n} \{R_i(x_j, y_j, z_j)\} \}$$

In the above formula, $m$ represents the number of all collision avoidance paths; $n$ represents the number of all points on a collision avoidance path; $R_i(x_j, y_j, z_j)$ means the collision risk degree of the $i$-th collision avoidance path on the $j$-th coordinate $(x_j, y_j, z_j)$.

In terms of economy, it is mainly to minimize the path to avoid collision. The objective function is as follows:

$$\min_{i=1}^{m} \left\{ \sum_{j=1}^{n} \sqrt{(x_{j+1}' - x_j')^2 + (y_{j+1}' - y_j')^2} \right\}$$

In the above formula, $x_j'$ represents the abscissa of the $j$-th point on the $i$-th collision avoidance path, and $y_j'$ represents the ordinate of the corresponding point.

After the objective function is determined, the genetic algorithm in intelligent computing is used to make decision to avoid collision. Take the parameters of your own vessel and the encountered vessel as input, and the parameter types include width, height, length, position coordinate, navigation speed, operation direction, etc. Calculate the path risk, store the acceptable risk to the initial population, and then calculate the fitness of all individuals. Then select the parent, carry out the cross mutation operation, and then calculate the risk of the path. Determine whether the risk degree is acceptable. If it is acceptable, store it in the offspring population. Otherwise, replace it with the parent. After storage in the offspring population, determine whether the optimal conditions are met, if so, output the optimal solution, otherwise recalculate the individual fitness value. Cycle the above process.

3. Experiment
Based on SIHC simulation platform, this paper studies the collision avoidance of inland ships. The situation of inland river is more complicated than that of sea. It is necessary to consider not only the limitation of ship channel, but also the upstream and downstream flow of inland river and the bifurcation of river. In this paper, a simulation model is built to carry out ship collision avoidance test and risk analysis. The length, height and width of the ship are taken into consideration, and the decision-making optimization method of avoiding collision of inland ships is explored by simulation from two situations of avoiding collision of two ships head-on and collision between ships and bridges.

4. Results
Result 1: Avoid collision when two ships meet face to face
In inland waterways, the common problem is that two ships will sail face to face. And the banks on the left and right sides are limited in width. In the simulation experiment, the speed of the ship is set to 6 meters per second, the starting point coordinate of the ship is $(0,0)$, and the ship moves from the left side to the right side of the simulation platform. The encountered ship sailed from right to left at a
speed of 3 meters per second, starting at the coordinates of (1900, 0). In the whole simulation process, the direction and speed of the encountered ship are kept constant.

The initial population number is 115, the path point to avoid collision is set to 10, the cross probability is set to 83%, and the variation rate is 7%. After 630 generations of breeding, the population produces the best path to avoid collision. The schematic diagram to avoid collision is shown in Figure 1. In the figure, the black triangle is the ship with collision avoidance behavior, and the blue triangle represents the ship in constant state. The two ships met at coordinates (1300, 0) and successfully avoided collision.

![Figure 1. Simulation results of collision avoidance between two ships.](image)

Further observation of the change in the risk of the vessel at different positions in the collision avoidance path is shown in Figure 2. It can be seen from Figure 2 that the two ships have reached the maximum risk when they meet, but the maximum risk is acceptable. In the process of avoiding collision, the ships keep a certain distance from the ships they encounter, and the path to avoid collision is relatively safe.

![Figure 2. Risk change of two ships meeting.](image)

Result 2: Avoid collision between ship and bridge

Considering that bridges and other buildings often appear in inland rivers, a three-dimensional model is built here. The initial starting position of the ship is 2000 meters away from the bridge, and the lowest point of the bridge is in the middle of the bridge. Therefore, in order to avoid collision, it is necessary to navigate to both sides of the river in advance, and return to the central line of the river after passing the bridge. When the ship reaches the lowest point of the bridge (x = 1090m), its risk degree reaches the maximum value, which is within the acceptable range. If the ship maintains the original sailing direction, the risk will reach 0.5 if it passes through directly, and the risk will be lower than 0.033 after the successful detour. The change of the risk is shown in Figure 3.
5. Conclusions
Because of the complex conditions such as the width of the river, the density of navigation and the bridge facilities, the collision accidents on the inland ships occur frequently. The research on Decision Optimization of collision avoidance for inland ships is helpful to reduce the occurrence of related accidents. Under the premise of avoiding collision accidents, how to achieve the effect with more safe and economic measures is a problem that the industry pays close attention to. It is hoped that the research of this paper can provide a reference for the safe navigation of related ships.

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