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Three-dimensional TSP seabed search model based on genetic algorithm

——First aid for the lost submersible

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Abstract: The paper presents a three-dimensional TSP (Traveling Salesman Problem) search model based on genetic algorithms to efficiently locate a lost submersible in the deep sea. The model takes into account the influence of underwater terrain and predicts the submersible's position using a genetic algorithm that optimizes the search path. The search probability as a function of time is also determined to prioritize search points closest to the main ship. The model simplifies the search process by assuming constant speed travel and ignoring mutations for operational efficiency. The conclusion highlights the model's high efficiency and adaptability, while acknowledging the need for improved accuracy in position prediction, especially under extreme conditions affecting the submersible's trajectory.

Keywords: Submersible Search; Genetic Algorithm; Three-dimensional TSP Model; Search Probability

1. Problem Background

The deep sea is like poetry, mysterious and beautiful, and hiding endless secrets, making countless explorers in the heart.Like land traffic, the submersible as a sea navigator, especially under the influence of ocean flow, seawater density, and unknown terrain, the risk is not reduced. The United States Coast Guard said on 22 June 2023 that the United States deep-sea submersible, which had disappeared on the way to examine the wreck of the Titanic, had suffered a 'catastrophic implosion' near the wreck site, killing all five crew members. Submersibles in the deep sea may face mechanical failure, such as the loss of propulsion, etc., may face with the main ship communication interruption resulting in the transmission of information is not smooth, as well as sudden changes in the underwater environment and other issues.

And underwater, accurate position prediction is crucial for navigation and path planning. Once the predicted position information is available, how can these positions be searched in the shortest possible time? When a submersible is in distress, regulators and rescue teams need to determine initial deployment points and search patterns to minimise the time to locate a lost submersible. There is also a need to determine the probability of finding the submersible as a function of time and cumulative search results. In this paper, a search model will be developed to address this problem.

2. Assumptions and Justifications

- Assumption: Assume that the search and rescue equipment maintains a constant speed during the travel distance, ignoring the acceleration and deceleration distance at each location point.

Justification: Because our solution searches along the path, each location point is very small relative to the entire path and sea area, so we can assume that the device maintains a constant speed during travel, thereby simplifying the model.

- Assumption: In order to simplify the search model and speed up the operation efficiency of the model, we do not consider the occurrence of mutations.

Justification: Because in the process of genetic algorithm, the optimal path has already appeared in the initial population, and mutation is not needed to generate the optimal path, so we do not consider mutation in order to simplify the model and speed up the operating efficiency of the model. of production.

3. Search model

3.1 Basic thoughts and methods

After the submersible is lost, it will lose contact with the main ship and cannot transmit information, status, environment and other information in real time. Faced with complex uncertainties, we must find the position of losing a submersible in the shortest time. Search at this location needs to establish a model to recommend the initial deployment point and search mode of search equipment. According to the prediction model of the previous problem 1, when K+1 is found to be lost in the submersible, the main ship can speculate that the position point of the submersible at the k+1 time at the time of the position speed received by K received at the previous moment. Since the density of ocean flow and seawater density in the location prediction model is considered in the error, this question only considers the influencing factor of the underwater terrain.

According to the predicted location point and underwater terrain data, we establish a three -dimensional TSP model based on genetic algorithms.

The TSP problem can be described as the selected three -dimensional terrain surface has determined multiple predicted position points. By solving the distance between each two position points, the search device uses the location of the main ship on the sea level as the starting point as the starting point. Start, search for all position points and search only once, and return to the initial position point at the same time to seek the shorter three -dimensional circuit with the shortest distance, so as to find the position that the submersible may be lost in the shortest time to find the soleer.

The genetic algorithm is reflected in a circuit composed of multiple position prediction points to represent a “chromosome” and randomly given the initial “chromosomes”, that is, the initial group (initial path) before performing genetic evolution. The principle of survival, copy the winning “chromosomes”, and generate a better sub -generation “chromosomal” (new child path) through cross -crossing and mutation strategies; so through the evolution of each generation Outstanding circuit order.

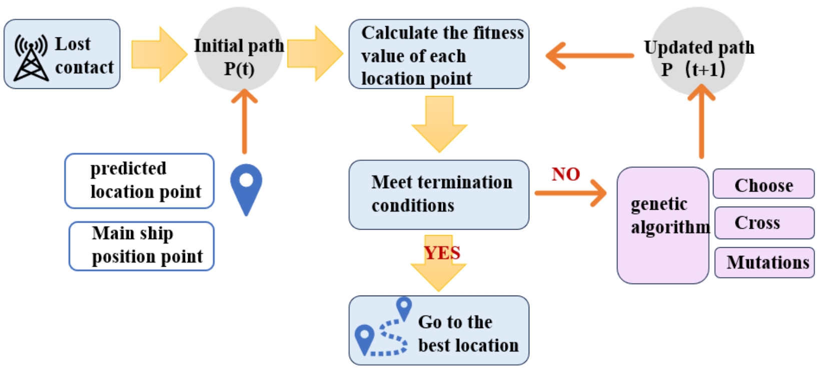

Figure: Optimal search path - application of genetic algorithm principles

3.2 Three-dimensional TSP search model based on genetic algorithm

3.2.1 Digital terrain map preprocessing

Since we need to consider the possibility of the search path, we need to collect a three-dimensional seabed topographic map of the target sea area, compare the seabed topographic data with the straight line segment data between two points, when the shortest path between the two search points When we need to cross the terrain, we believe that this shortest path is unreasonable, and we need to re-adjust the path and use the distance between two points along the seafloor terrain as the minimum value.

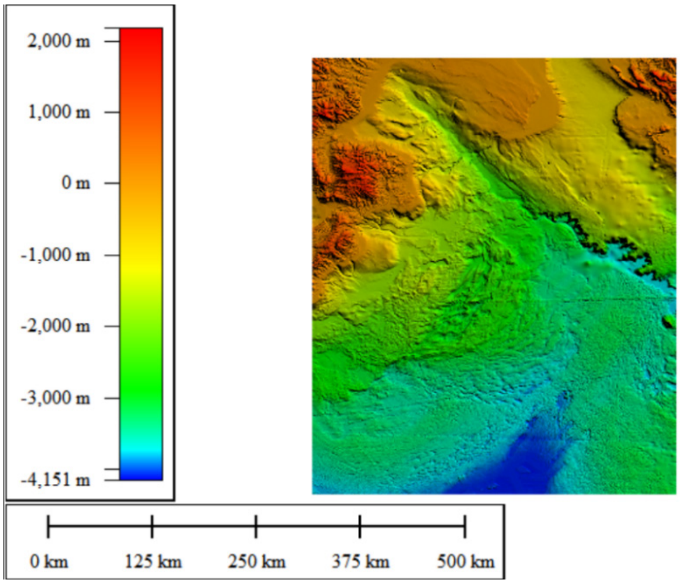

Figure Ionian Sea topographic map

3.2.2 Initial population setting

Use a positive integer order to encode the chromosomal. Each positive integration in a order of order represents a position point. The arrangement representatives of different orders pass through the order of each city point. In this way, a chromosomal represents a potential and feasible path solution.

In addition to the position points (N) that the submersible predicted by the above model 1, we also need to set the position of the main ship (x_0 , y_0 , z_0) (where z_0 is a fixed value, that is, in the sea, that is, in the sea Looking for the most suitable point on the plane), our search path meets that all submersibles from the main ship may exist and return to the location of the original main ship.

Define a matrix with s rows and m columns to represent the group. m is the number of positions + 1, that is, n + 1, s is the number of individuals in the sample. If we get 30 position points in the model 1, we can convert 30 relatively certain position values (when T remains unchanged, there is a fixed (x_i (t) , y_i (t) , z_i (t)) For (x_0 , y_0 , z_0), the TSP problem that z_0 is known and is the height of the sea level), at this time m takes the value of 32, the first 31 elements of each line in the matrix indicate the position number of the pass, the last element of the last element Indicates the value of the adaptation function, that is, the distance d(j) request for each individual.

At the same time, we need to pay attention to changes over time. The position of the prediction point will change. When the search device is only j+1 from the forecast point j+1, the length between the two observation points is as follows:

$$t_j = t_{j-1} + \frac{d(j)}{v} \tag{1}$$

$$d(j+1) = \sqrt{\left(x_{j+1}(t_j) - x_j(t_j)\right)^2 + \left(y_{j+1}(t_j) - y_j(t_j)\right)^2 + \left(z_{j+1}(t_j) - z_j(t_j)\right)^2} \tag{2}$$

3.2.3 Fitness function and selection, crossover and mutation

The quality of each point in the initial path is different. In order to obtain the best possible results, the best path must be selected during each iteration. point. When performing genetic selection, a fitness function is established as a criterion for evaluating whether an individual is excellent. The distance matrix can be used to obtain the loop length of each prediction point. The objective function is the minimum value of these loop lengths, and the reciprocal value of the objective function is taken as the fitness value. According to the definition of m, there are m-2 combinations of two position points. The objective function and adaptive function are as follows:：

$$J(m) = \sum_{j=1}^{m-2} d(j) \tag{3}$$

$$f(m) = \frac{1}{J(m)} \tag{4}$$

Since the location of the main ship is not fixed, when the time is fixed, the target function f(m) is actually a dual function of X, Y. The maximum value of f(m) about x, y. When the f(m) takes the maximum value, the value of x, y at this time (x_0 , y_0) are determined, you can know the location of the main ship.

In order to accelerate the speed of the genetic algorithm iteration, we adopt the optimal preservation strategy method, and the individual with the largest adaptation in the group directly replace the individual with the smallest adaptation. They do not cross -cross and mutate operations, but directly copy to the next generation, so as not to cross and mutate operations to destroy excellent answers in the population.

In terms of cross, we need to choose two cross points according to randomly; follow the order of the same sub -segment position of the same sub -segment according to the corresponding location; finally, for different circuit skewers data Y1, Y2, if the new location is exchanged, the new location is newly located, the new location is One position point in the circuit and the original father's loop Y1 are repeated, and we use this position point to replace the new position point of the same order in the Y2 point as the position of the position. The same method is used for C2.

The above two methods have reached the optimal path after certain times, and we do not consider the production of mutation in order to simplify the operating efficiency of the model to speed up the model. The results of the genetic algorithm are as follows:

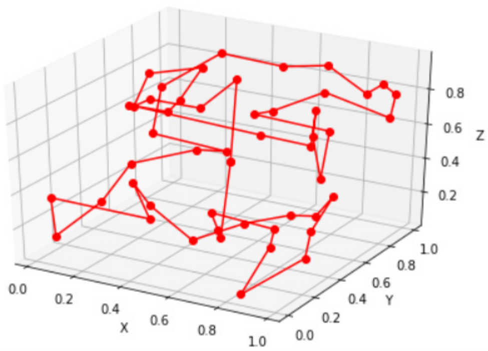

Figure optimal path graph

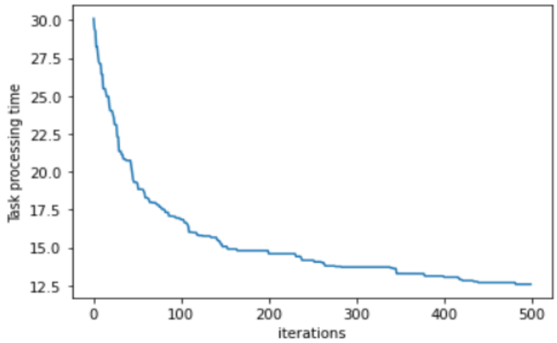

Figure genetic efficiency map

3.2.4 Determining search probability

Using the genetic algorithm, we can calculate a more efficient search method. In order to make the search efficiency more efficient, we set the probability of finding the submersible at each predicted point to be the same, far away from the main ship. The nearest point is set as the initial search point, and the equation of search probability changing with time is:

$$\text{当}\frac{\sum_{j=1}^{i} d(j)}{v} < t < \frac{\sum_{j=1}^{i+1} d(j)}{v} \tag{5}$$

$$P = \frac{i}{m} \tag{6}$$

4. Conclusion

Aiming at the way of searching the submersible after losing connection on the seafloor, we constructed a three-dimensional TSP seafloor search model based on genetic algorithm. Firstly, combined with the predicted position points after lost connection, we establish the distance matrix between multiple position points with time change by considering the influence of seabed topography, plus the problem of search route is transformed into a TSP problem; secondly, based on the above calculation results, we consider the multivariate function function of probability of time, and find out the position of the main ship when making the path sum to be the shortest by seeking the maximum value of the multivariate function method. Finally, the search path solution is continuously optimised with the help of the evolutionary process of the genetic algorithm in order to determine our search route and take the search point closest to the main ship as the initial search position. A function of our discrete probability distribution over time is also derived.

We believe that our model can complete the search with a high efficiency, work and have a strong coordination and adaptability, but the accuracy of our model position prediction needs to be enhanced and improved when the drastic changes in the trajectory of the submersible brought about by extreme weather and other factors.

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