# The robot path optimization of improved artificial fish-swarm algorithm

**Jiansheng Peng[1, 2*]**

[1]*National Key Laboratory of Communication, UEST of China Chengdu 610054, China*

[2]*Department of Physics and Mechanical & Electronic Engineering, Hechi University, Yizhou 546300, China*

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**Abstract**

The robot path optimization solution is seek a collisionless path from starting point to end point to make the robot get the shortest route go along with planning path. Let robot path optimization problem map to mathematical model TSP (Traveling Salesman Problem) to resolve it, and make the corresponding algorithm realize robot path planning optimization was introduced in this paper. According to existent insufficiency of traditional artificial fish-swarm algorithm, using improved artificial fish-swarm algorithm optimizes the robot path planning, and stands out the superiority of improved artificial fish-swarm algorithm. The main improved aspect of artificial fish-swarm algorithm is increases examine link in foraging behaviour.

*Keywords:* robot path optimization, Traveling Salesman Problem, improved artificial fish-swarm algorithm, foraging behaviour

## 1 Introduction

Optimization issues are always the researchers' potluck, no matter in engineering research field or scientific research field, its raging flames is never disappearing. As traditional optimization method cannot satisfied the requirement of persons solve the complex questions. So many home and abroad researches step on explorer multi-intelligence optimization algorithm journey, uncovered all kinds of mystery of optimization algorithm. According to characteristics of all sorts of optimization algorithm, select the superior and eliminate the inferior, perform the multi-mixture intelligence optimization algorithm climax [1]. Robot path optimization is one of most important robotics' researches fields, not only can make robot walk optimization path route, but also can reflect the robot accomplish the working performance well. It is play an important role in path planning optimization. Robot path planning optimization can apply to robots obstacle avoidance walk in known environment, robots put out fire, robots rescue and relief work, robots process route planning [2], mobile robots clean tank [3-5], robots carry out the weld and assembling and so on. It is save robots work time and reduce devoted fund. TSP is a particular case miniature of robot path planning, which is to say the TSP is equivalently to robots go N different places to pick up goods, and then go back to original location, every place just can go over once to seek the shortest path. So it can abstract to the research of robot path optimization from traveling salesman problem. There is scientific feasible evidence based to verify the effectiveness of improved artificial fish-swarm algorithm, and it also brings energy that applies to improve artificial fish-swarm algorithm.

## 2 The Description of traveling salesman problem

TSP is one of typical combinatorial optimization problem, which is easy to describe but hard to solve. The complexity of problem rises with the way of problem's scale increase is in the exponent, which even may produce combination explosion. It is play an important role to research it. TSP problem can describe as: if there are n cities, the distance between every two cities is known, a merchant go out to sell his goods from any city, it's require to go around these n cities and every city just can visit only once, go back to original at last. How to traversal can make all journeys be the shortest. The substance of TSP is finds the shortest Hamilton path in n nodes' complete graph, and the robot path planning is so.

The mathematical model of TSP problem describes [6] as:

$$\begin{cases} \min \sum \mathrm{d}_{ij} x_{ij} \\ s.t. \sum_{i=1}^{n} x_{ij} = 1, i = 1,2 \ldots n \\ \sum_{j=1}^{n} x_{ij} = 1, j = 1,2 \ldots n \\ \sum_{i,j \in s} x_{ij} \le |s| - 1, 2 \le |s| \le n-2, s \subset \{1,2,\ldots n\} \\ x_{ij} = \{0,1\}, i, j, = 1,2 \ldots n, i \ne j \end{cases}$$

* ***Corresponding author*** e-mail: Sheng120410@163.com

TSP has symmetry and asymmetry, when $d_{ij} = d_{ij}$, it is symmetry distance TSP, or it is asymmetry distance TSP.

The first formula above is an objective function, which expresses the distance between merchant traverse path of all cities and go back again is the minimum. The second formula expresses the merchant just right arrive at city i one time. The third formula expresses merchant just leave city j one time, together with the second formula, they are express every city has already visit once, thus avoid sub-loop happened. The fourth formula carries the merchant's point that cannot form loop in any city proper subset. Among them, $|s|$ expresses the number of set s elements. The decision variable in fifth formula $x_{ij} = 1$, expresses the trail path include in merchant from city i to city j, $x_{ij} = 0$ means the merchant is not select this way to travel path. The constraint of $i \neq j$ making the number of decision variable reduced as n*(n-1).

## 3 Fish-swarm algorithm introduction and correlation definition.

### 3.1 FISH-SWARM ALGORITHM INTRODUCTION

Fish-swarm algorithm introduction, which was put forward by Li Xiaolei [1] and others, is a new type swarm intelligent optimization algorithm, which is, imitates the fish's behaviour in nature. Use the top-down design idle has such characters: the requirement of objective function's properties, initial value and parameter is not high, parallelism, global superiority, speediness, traceability and so on. It also has shortcomings: The earlier stage of convergence speed faster than later obviously; the choice of algorithm parameters can effect on convergence speed and result accuracy; the more artificial fish-swarm number and the time need more; wide find optimization range and small changes may lead to convergence speed slow, and the search efficiency will be unsatisfactory.

There are four basic behaviours for artificial fish: (1) foraging behaviour: artificial fish swim to the high food concentration; this is the foundation of algorithm convergence. (2) Bunching behaviour: artificial fish swim to the high food concentration and not very crowd around fish-swim centre; this is the stability and global safeguard of algorithm convergence. (3) Rear-end behaviour: artificial fish rear-end individual fish which with high food concentration and not very crowd around individual fish; this is add the algorithm convergence's speed ability and global. (4) Random behaviour: artificial fish swim freely in water, expand the search range. According to the requirement and property of problem, rational planning and setting artificial fish-swarm algorithm model to solve it. Lump together, the main idea is generate a certain number of artificial fish-swarm, search optimize path in search field by imitate fish behaviour. In TSP, the quantity of cities is proportional to artificial fish-swarm scale, means the more the cities quantity, which robots need to travel, the more the artificial fish-swarm individual, otherwise less.

### 3.2 FISH-SWARM ALGORITHM CORRELATION DEFINITION

Definition 1: Suppose artificial fish's current location state is $X_i = (x_1, x_2, ......x_n)$, artificial fish's next state is $X_j = (x_1^v, x_2^v......x_n^v)$, and then this process can be expressed as: $x_j = x_i + visual * r$, i=1,2……n, $X_{next} = \frac{X_j - X_i}{\| X_j - X_i \|} * Step * r$

Definition 2: Suppose G is artificial fish's set, there is $N(X,k) = \{X^{'} \mid d(X, X^{'}) \leq k, X^{'} \in G\}$ to artificial fish X, $N(X,k)$ called X's k neighbourhood, $X^{'} \in N(X,k)$ expresses the X's neighbourhood in distance k.

Definition 3: The centre location of artificial fish $X_1, X_2, ..., X_q, ..., X_m$ is:

$$Center(X_1, X_2, ..., X_q, ..., X_m) = \left( \frac{\sum_{q=1}^{m} x_{q1}}{m}, \frac{\sum_{q=1}^{m} x_{q2}}{m}, ..., \frac{\sum_{q=1}^{m} x_{qj}}{m}, ..., \frac{\sum_{q=1}^{m} x_{qn}}{m} \right)$$

$(i = 1, 2, ..., m, j = 1, 2, ..., n)$.

In this form, $Center(X_1, X_2, ..., X_q, ..., X_m)$ expresses centre location of artificial fish $X_1, X_2, ..., X_q, ..., X_m$, shows the every components average of selected m fish.

Definition 4: The distance between artificial fish expressed as $d_{i,j} = \| x_i - x_j \|$.

Definition 5: step expresses moving step of artificial fish, date is crowding factor of artificial fish, try_number is artificial fish's maximum explore time, visual is visual scope of artificial fish and maxgen is artificial fish's maximum iterate time.

Definition 6: $X_i$ is current artificial fish, $X_j$ is next state artificial fish, $n_f$ means number of partner, $X_c$ is fish-swarm centre, $X_c$ is food concentration in fish-swarm centre.

In TSP, initialize every artificial fish is one of random permutations which including all cities number to every artificial fish, that is encoding reasonably. Provide a city number to arrange randomly can initialize an artificial fish. According complexity of problem and algorithm need to create a certain artificial fish. This can be used to similar robot path optimization issues. Its nature is same with TSP. Artificial fish centre is the number of city serial number which appear the most times, statistics n places that are different from each other and the number appear more times, the centre position is appear the most times in the same place. The distance between two fish is the count of different city serial number in one place.

These two fish are neighbour if the distance less than visual, means a fish in another fish's field. The city sort of two artificial fish is: $A = \{a_1, a_2 ... a_n\}$ and $B = \{b_1, b_2 ... b_n\}$ the distance between them is $dis\tan ce(A,B) = \sum_{i=1}^{n} sign(|a_i - b_i|)$ in it, $sign(x) = \begin{cases} 0, x = 0 \\ 1, x > 0 \\ -1, x < 0 \end{cases}$.

## 3.3 THE BASIC BEHAVIOR OF ARTIFICIAL FISH

### *3.3.1 Foraging behaviour*

*Foraging behaviour is* searched arrange information including city position serial number in field by current artificial fish. Change position among m cities by itself randomly. It is need to satisfied $m \le \frac{1}{2} visual$, thus can ensure the artificial fish foraging in visual range. If there is more optimize individual fish status than current fish status when foraging, then use artificial fish which more optimize than current fish status to take place of it. That is to say, travel city path is shorter than current artificial fish information walk city route. If execute try_number times with above behaviour in common, foraging behaviour failure, then carry out random behaviour.

### *3.3.2 Bunching behaviour*

Find all neighbours of current fish at first, then statistic every city serial number, which appears the most same city serial number in one place all neighbours in current artificial fish field. The most appear serial number in each column formed arrangement is artificial fish centre. If there is some serial numbers appeared times are greatest at the same time, value a number among them randomly. If there is repeated city serial number in one row n column, disposed it with missing code replace repeated serial number to make it as without repeat arrangement from 1 to n. If the centre city path less than current city path and satisfied with $\frac{Y_c n_f}{Y_i} < \delta$, use several bunching centre status position serial number replace corresponding current artificial fish status position serial number, the new status artificial fish act as next status artificial fish. If there is repeated code in arrangement number after replacing one row n column, it should be processed. It will execute foraging behaviour once bunching behaviour failed.

### *3.3.3 Rear-end behaviour*

Search the highest food concentration individual Xmin in nf neighbourhoods of current artificial fish neighbourhood space N (X, visual), the food concentration is Ymin. If $\frac{Y_{\min} n_f}{Y_i} < \delta$ and $Y_{min} < Y_i$, make the status of most optimize artificial fish Xmin as current fish status. That is to say, if there is information which the neighbourhoods of artificial fish included in travelled city walk route shorter than itself and around it not crowded, then use several city position serial numbers of artificial fish short city route randomly instead of current artificial fish city position serial number. Use the same way to process it to generate reasonable city position serial number as next status fish. It will execute foraging behaviour if rear-end behaviour failure.

### *3.3.4 Random behaviour*

Random behaviour provides artificial fish a city arrangement randomly in artificial fish sensing range. Current fish $X_i$ swim in visual range randomly; this is a default behaviour of foraging behaviour. Realize random behaviour rather simple, it increase artificial fish search range.

## 3.4 THE IMPROVEMENT OF FISH-SWARM ALGORITHM

Add examine link: artificial fish of improved foraging behaviour add a examine link on the basis of primary artificial fish foraging behaviour. It means artificial fish seek k different status in its visual range, choose searched most optimize status as current artificial fish's next status. Thus can decrease blindness of artificial fish find optimization, and it can make artificial fish have multiple choices in every swimming. This can enhance efficiency greatly, and get better value faster. In TSP, try_number each time, current artificial fish searching in neighbourhood field, it will change randomly among m cities' position. After repeating k times, choose the best status enter into next try_number until reach the most tempter times. The possibility will be more likely to find current status individual fish status as next status better than current fish status.

The pseudo-code descriptions of adding examine link foraging behaviour as follows:

```
float Artificial_fish::AF_prey( )
{
  Xmin=Xi; //Xmin is own the most optimize food
         //concentration which search in visual range
  Ymin=Yi; //Ymin express abundance food that
         //own the most optimize food concentration
         //which search in visual range.
  for(i=0;i<try_number;i++)  // try_numberis artificial
                             //fish tempter times
  {
    for(k=0;k<10;k++)    //examing other fish status
                         //10 times in visual range
    {
```

Xj = Random(N(Xi,visual)); //search next status //randomly in neighborhood field
If (Ymin>Yj) //if it satisfied searched fish own //food concentration better than most //optimize fish food concentration Ymin.
{
Xmin=Xj;//value the status of fish Xj to Xmin
Ymin=Yj; // value the food concentration of //fish Xj to Xmin
}
}
If (Ymin<Yi) //judge searched most optimize food //concentration whether better than //primary food concentration
$X_{i|next} = X_j$; //use artificial fish which searched //own most optimize food concentration as next status
else //or moving randomly
$X_{i|next}$ = Random*step;
}
Return AF_foodconsistence ( $X_{i|next}$ ); //return food //concentration value of next status artificial fish
}

## 3.5 ALGORITHM PROCEDURE AND FLOW DIAGRAM

Step (1): initialize fish-swarm AF and current fish yu and set parameter: crowding factor delta, tempter times try_number, examine times k, sensing range visual, greatest iterations maxgen, the number of artificial fish-swarm individual N, city numbers M, moving step length step.

Step (2): initialize variable: store most optimize artificial fish status zui_you on bulletin board, store most optimize artificial fish food concentration zui_min on bulletin board, store food concentration Y of N artificial fish, store data shu_ju of total distance, store next status AF_next of N artificial fish, store initialize food concentration Y_next of artificial fish next status.

Step (3): output random solution, which get of walk route map and total distance of current fish yu.

Step (4): make optimize, search most optimize artificial fish individual in initialized artificial fish, update bulletin board and record total distance in the meantime.

Step (5): begin iteration, make behaviour judgment choose. Call functions foraging behaviour, bunching behaviour, rear-end behaviour and random behaviour, compare and judge which behaviour should be execute for artificial fish to get the best next status and food concentration, then choose the best one to execute. At the same time, update the best artificial fish status and food concentration on bulletin board, as well as update artificial fish-swarm status and them food concentration. Record total distance witch each iteration get.

Step (6): draw curve graph of every optimize process and most optimize solution path diagram.

The algorithm flow diagram is followed 3.6.1:

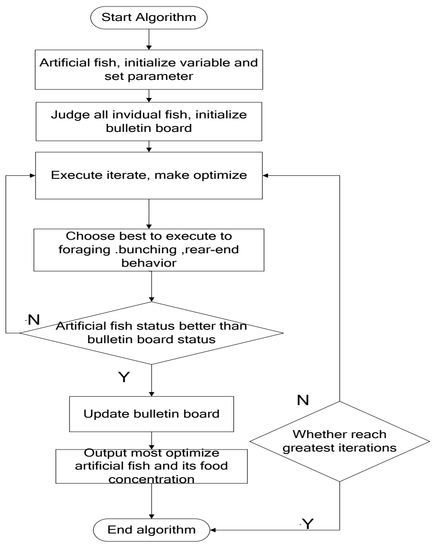


FIGURE 1 Algorithm flow diagram

## 4 Simulation experiment and result analysis

Adapt to MATLAB R2010a as programming software, solute on computer which CPU is 792MHZ, memory is 2.00GB, operating system is Windows XP.

Table 1 shows the data [7] for 14 cities BURMA14 position coordinate in standard TSPLIB library to use to validate the effectiveness of improved artificial fish-swarm algorithm. It also uses to provide thinking which solve robot path optimization problem better by the application of this algorithm. Set artificial fish-swarm individual number N=10, cities number M=14, visual range visual=9, tempter times try_number=8, examine link times k=10, crowding factor delta=6, moving step length step=3, maximum iterate time maxgen=20, let 10 fish search optimization. These 14 cities may exist the route is $\frac{(14\text{-}1)!}{2} = 3113510400$ if use enumeration method, the best known solution is 30.8785.

TABLE 1 the data for the TSP problem of 14 cities

| City Number | | | City Number | | |
|---|---|---|---|---|---|
| | abscissa X | ordinate Y | | abscissa X | ordinate Y |
| 1 | 16.47 | 96.10 | 8 | 17.20 | 96.29 |
| 2 | 16.47 | 94.44 | 9 | 16.30 | 97.38 |
| 3 | 20.09 | 92.54 | 10 | 14.05 | 98.12 |
| 4 | 22.39 | 93.37 | 11 | 16.53 | 97.38 |
| 5 | 25.23 | 97.24 | 12 | 21.52 | 95.59 |
| 6 | 22.00 | 96.05 | 13 | 19.41 | 97.13 |
| 7 | 20.47 | 97.02 | 14 | 20.09 | 94.55 |

The most optimize path orbit diagram and iterate change of optimize process which get by improved artificial fish-swarm algorithm shown as Figure 2 and Figure 3.

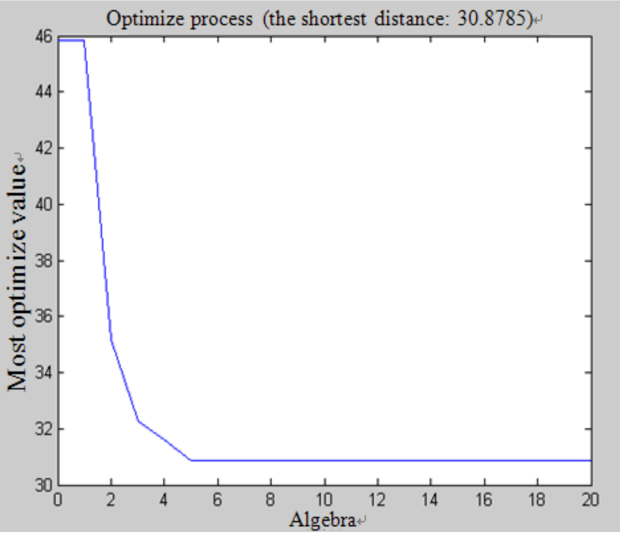


Figure 2 The most optimize path orbit diagram

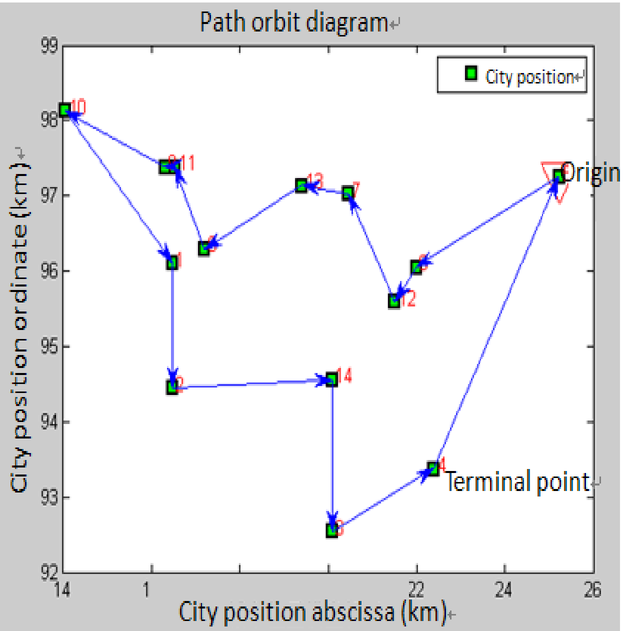


Figure 3 Optimize process curve

The pictures shown that the experiment result get the shortest distance: 30.8785. The walk route is: $5\to6\to12\to7\to13\to8\to11\to9\to10\to1\to2\to14\to3\to4\to5$, the origin position could not be affected if walk on this circus, that is the shortest path. The convergences iterate times are 5 generations. The convergence extent bigger from first generation to second generation, it tend to optimum value after second generation and get the optimum value on fifth generation.

TABLE 2 Comparison performance of several methods

| | Text algorithm | Literature algorithm |
|---|---|---|
| **sward number** | 10 | 100 |
| **average iterate times** | 5 | 80 |
| **average search range** | 10*5=50 | 100*80=8000 |
| **the percentage of algorithm search space** | $\frac{50}{(14-1)!/2}=0.0000016\%$ | $\frac{8000}{(14-1)!/2}=0.00026\%$ |
| **optimum value** | 30.8785 | 30.8785 |

The experiment result shows the application of artificial fish-swarm algorithm optimization has already achieved well convergence efficiency. Use 10 fish artificial fish search parallel; iterate 5 times can get the optimum value 30.8785. Compared with literature [8], improved particle algorithm search optimization reduces the search range about 99%. The convergence efficiency has improved much, reduce about 98%. Improved artificial fish-swarm adds the examining link on foraging behaviour. The obvious advantage is shrink the search range, speed up the convergence speed, improved much algorithm optimize performance. At the same time, it applies in the solution of robot path optimization problem, can search the shortest path fleetly.

## 5 Conclusions

Come up with artificial fish-swarm algorithm has become a highlight in optimization field. Improved artificial fish-swarm algorithm has line out a beautiful scenery line in optimization field, appeals to scholar's favourites who keen on algorithm. Article analysis what catch hold of TSP and robot path optimization have the same substance. Solved 14 cities traveling salesman problem well by using artificial fish-swarm algorithm, and compared with improved particle algorithm to observe the merits of convergence speed and result. Verified the superiority of improved fish-swarm algorithm's performance, open up the solution road of optimize robot path problem. The solution of robot path optimization problem can be used to robot multiple operation field, improved robot work performance, enhance the economic benefit. Meanwhile, it provide a nice platform on optimize mind to other manufacture, agriculture, national defence, engineering, transportation, finance, chemical engineering, energy sources, communication and so on field, make a huge contribution to national economy.

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## Authors

**Jiansheng Peng**

**Current positions, grades:** The Hechi university teaching in 2004, Associate Professor in 2013, Engineers titles in 2010, China Institute of Atomic Energy Ph.D. in 2010, University of Electronic Science and Technology postdoctoral fellow in 2013.

**Research direction:** Robot path planning navigation, development and application of embedded.