Research Journal of Applied Sciences, Engineering and Technology 5(6): 2042-2047, 2013
DOI:10.19026/rjaset.5.4747
ISSN: 2040-7459; e-ISSN: 2040-7467

Submitted: July 26, 2012 Accepted: September 08, 2012 Published: February 21, 2013

Research Article

Robot Global Path Planning Based on Improved Artificial Fish-Swarm Algorithm

[1, 2]Jiansheng Peng, [1]Xing Li, [3]Zhi-Qiang Qin and [2]Guan Luo
[1]China Institute of Atomic Energy, P.O. Box 275-36, Beijing, 102413, China
[2]Department of Physics and Electronic Engineering, Hechi University, Yizhou, Guangxi, 546300, China
[3]Hunan University of Science and Technology, Xiangtan, Hunan, 411201, China

Abstract: In This study, a new artificial fish-swarm optimization, to improve the foraging behavior of artificial fish swarm algorithm is closer to reality in order to let the fish foraging behavior, increase a look at the link (search) ambient, after examining environment, artificial fish can get more status information of the surrounding environment. Artificial fish screened from the information obtained optimal state for the best direction of movement. Will improve the foraging behavior of artificial fish-swarm algorithm applied to robot global path planning, including the robot to bypass the analog obstacles selected three ways: go obstructions outside, go inside the obstacles, both away obstructions and went outside obstacles Thing achieve robot shortest path planning. Via the MATLAB software emulation test: the improved foraging behavior of artificial fish-swarm algorithm to improve the rapid convergence of the algorithm and stability, improve fish swarm algorithm to the adaptability of the robot global path planning.

Keywords: Artificially shoals algorithm, optimal algorithm, robot path planning

INTRODUCTION

Robot has used in many-sided at present such as industry, agriculture, service and aerospace, etc. All of these can be seen that the implement of robot. It needs to be moved to complete specific task in certain profession. So the robot path planning has become a hot issue. According to the partition of current academic circles, robot path planning can be divided into two types: global path planning based on environment information completely known and part path planning based on sensor information. However, the environment modeling of global path planning include: Visible Graph, Topological Method, Free Space, neural network method, etc. Free Space possess advantages, such as model simple, good achieve result. But it is difficult to model for Free Space in a complex environment.

Some scholars have researched the robot global path planning based on artificial fish-swarm algorithm, such as the based on artificial fish-swarm algorithm. The study is provided a way which the artificial fish-swarm optimizes robot path planning to Free Space (Nie and Zhou, 2008). Particle swarm optimization work in the aspect of robot global path planning is also to be researched by some scholars, such as the based on the mobile robot path planning of particle swarm algorithm. The study offered a particle swarm algorithm path planning based on Free Space (Huang *et al*., 2006; Wei, 2012). However, these two papers are searched with low precision, inefficient and other disadvantages. In order to improve the precision and efficient, it has to be the necessary improvement.

The application approximation algorithm to the energy consumption of the robot, considering the energy consumption of the linear motion, but did not consider the energy at the time the, the robot speed change and cornering consumption (Brooks and Kaupp, 2007; Zheng and John, 2006). The Optimization through genetic algorithms to optimize the robot's movement speed and energy consumption (Brooks, 1986; Wang *et al*., 2009). Using EGICA (Environment-Gene evolutionary Immune Clonal Algorithm) algorithm for robot joint trajectory planning, get to meet the optimal time and optimal energy trajectory path length constraint is not embodied (Xu *et al*., 2010). The assumption that the robot along the linear motion and speed does not change, is proposed an energy-saving motion control strategy to minimize the consumption function, due to the engineering robot is not along a linear motion, so is difficult to apply to the actual (Barili *et al*., 1995; Vasilyev, 2002). Order rate control method, using the proposed iterative search algorithm the saving speed change map, reducing the energy consumption of the robot (Chong and Byung, 2005; Xie *et al*., 2007). It can be seen, the current study is based on a point or two constraints path planning and rarely consider turning and speed changes. Therefore, in accordance with the actual situation of the robot traveling, planning a meet time, path and energy consumption of three the relative

Corresponding Author: Jiansheng Peng, China Institute of Atomic Energy, P.O. Box 275-36, Beijing, 102413, China

optimal path constraints, both in terms of energy-efficient or real-time algorithm has great significance.

Artificial fish-swarm is a swarm intelligence algorithm and the late-model intelligence algorithm. Simplicity, global superiority, rapidity, shadowing property and robustness. The individual of artificial fish hunt object by bunching behavior, rear-end behavior, foraging behavior and random behavior (Li and Qian, 2003). According to these four behaviors, artificial fish-swarm can transfer fish-swarm unconsciously to achieve more high-efficiency swarm search. But the fish-swarm algorithm is also has disadvantages with low convergence precision and low hunt efficient. The study enhances convergence precision and hunt efficiencies by improving foraging behavior. Meanwhile, it offers a technical to resolve the problem of robot path planning.

INTRODUCE RELEVANT DEFINITION

Relevant definition:

Definition 1: Vector x_i represents the i_{th} artificial fish state. The x_{inext} represents the i_{th} artificial fish percept next state.

Definition 2: Visual expresses the maximum range what artificial fish percept.

Definition 3: Y represents food concentration and then the food concentration of artificial fish i can be expressed as $Y_i = f(x_i)$.

Definition 4: Step expressed maximum step of ever movement of artificial fish.

Definition 5: δ expressed crowded degree factor, defined the crowded extent of artificial fish.

Definition 6: $d(x_1, x_2)$ expressed the distance of artificial fish x_1 and artificial fish x_2, the expression is $d(x_1, x_1) = \| x_1\text{-}x_2 \|$.

Definition 7: Definite a variable to record the optimal history what artificial fish searched. The variable is just like a call-board. So, it is called call-board variable.

Defined the artificial fish relevant behavior:

- **Foraging behavior:** In perception range, artificial fish i searches next state x_{inext} random. Artificial fish update state if the food concentration Y_{inext} is superior to the food concentration of current state Y_i, or it implements random behavior.
- **Bunching behavior:** The current state of artificial fish i is x_i and the range of artificial fish i percepts the home position food concentration is Y_c. Calculate the quantity of artificial fish n_c of perception scope. If formula $Y_c/n_c>\delta Y_i$ and $Y_i<Y_c$ established, it indicates there are lots of food and without crowd. Then artificial fish i forward into home position a step, or implement the random behavior.
- **Rear-end behavior:** Artificial fish i current state is x_i, search the most concentrative individual artificial fish j in current perception range and search the number of artificial fish n_f in perception range. If $Y_j/n_f>\delta Y_i$ and $Y_i\text{-}Y_j$ then it shows there are more food and not too crowd. Artificial fish i forward into artificial fish j a step, or implement the random behavior.
- **Random behavior:** Achieve random behavior is simple. Choosing a state randomly in visual field, move a step to this direction. It is a simulation behavior to natural fish. It ensures that the artificial fish flee sub maximum to hunt for maximum point.

Behavior assessment function: Artificial fish gain the corresponding food concentration Y_{inext}, Y_c, Y_j in perception range by bunching behavior, rear-end behavior and foraging behavior. Compared these three concentrations and select out the most maximal food concentration to compare with current state. If the food concentration is bigger than current concentration, then implement corresponding behavior, or implement the random behavior.

Improvement foraging behavior: It just can search around randomly one time for previous artificial fish-swarm algorithm. It can't usable reflection surrounding environment conditions to this once random research. The way of improve this issue is main to once search pattern improvement. Artificial fish get k states by searching surrounding environment randomly. Select optimal state to compare with current state from k states. If the food concentration is bigger than current concentration, then forward to the position of the state, or implement the random behavior:

$$f(x,y) = \frac{\sin(x)}{x} * \frac{\sin(y)}{y}$$

Solve the maximum problem of function: Maximum value point of this function is (0, 0). How to work out maximum value with fish-swarm algorithm. There is a obvious disadvantage in traditional fish-swarm algorithm that maximum value convergence precision is low. The fish-swarm algorithm of improving foraging behavior has resolved it. Improved foraging behavior pseudo-code is following:

```
Float Artificial-fish::AF-prey ()
{
    Xmax = Xi;
    Ymax = Yi; // Xmax Ymax express fish and food
    quantity which searched in visual scope and with
    the maximum food
    for (i = 0; i<try number; i++) //try_number is the
    movement of artificial fish.
    {
```

```
for (j = 0; j<20; j++)  //Hunt for 20 visual scope states.
    {
    Xj = Xi + R and ()*visual; //Search visual scope states randomly.
    If (Ymax<Yj) //The hunt state possess food quality more than current food quality Ymax.
    {
    Xmax = Xj; //It satisfied condition and implemented what the state Xj assigned to Xmax.
    Ymax = Yj; //It satisfied condition and implemented what the state Yj assigned to Ymax.
    }
    }
    if (Ymax>Yi) // To judge the searched optimal state value is bigger than former food state.
    Xi|next = Xi + R and () *step* (Xmax-Xi) /||Xmax-Xi||; //Move to the most optimal direction.
    else
    Xi|next = Xi + R and () *step; // Or it move randomly.
    }
    return AF-foodconsistence (Xi|next); // Return the state value after fish finish its movement.
}
```

The operating environment of following code is: program run environment is AMD Sulong dikaryon 2.91 Ghz, OS is Windows XP, program executive software is Microsoft Visual C++ 6.0. It just searches randomly one time in tradition fish-swarm algorithm foraging behavior. The visual scope visual = 3, step length step = 0.3, crowding factor δ = 0.618, iterations is 50, 10 artificial fishes. Mapping result with MATLAB 6.5 is followed Fig. 1.

In Fig. 1, blue point expressed artificial fish. It can be covered that only an artificial fish arrive at maximum point. The data of call-board display as followed is simulation result: maximum point (0.046247, 0.005745), maximum value $f(x, y)_{max}$ = 0.9996.

The parameters define of artificial fish improved foraging behavior as followed: foraging behavior random search k = 20, the visual scope visual = 3, step length step = 0.3, crowding factor δ = 0.618, iterations is 50, 10 artificial fishes. Mapping result with MATLAB 6.5 is followed Fig. 2.

It declared that most artificial fish are rid of what sub maximum focus around maximum. The result of call-board is (-0.023021, 0.007922), f (x, y) max = 0.9999. The improved foraging behavior artificial fish has optimal research result and high precision. There are more artificial fish get to maximum point.

From simulate result, it can be concluded that: if foraging behavior search surrounding environment randomly only one time, artificial fish implement foraging behavior or not is provided with contingency.

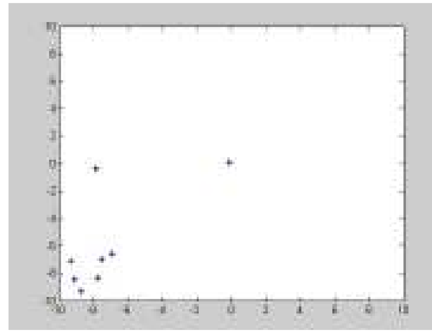

Fig. 1: Simulation picture of artificial fish

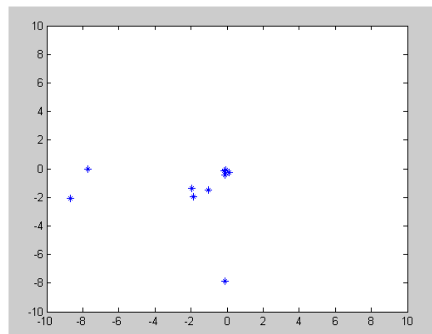

Fig. 2: Improved foraging behavior simulation picture of artificial fish

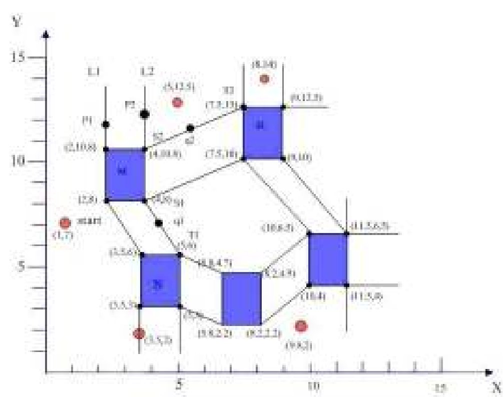

Fig. 3: Robot obstacle avoidance rout chart

After hunting k times, improved foraging behavior gain multi-state values. It reduced the foraging behavior contingency swinging and increased fish-swarm search efficiency.

THE RESEARCH OF ROBOT SHORTEST DISTANCE WORK PATH

System describe: In the Fig. 3, robot obstacle avoidance coordinate, red circle is the destination of robot needs to arrive. It needs to walk 5 places to hunt for the shortest path. Thus, how does it search the shortest path? We resolve the way of robot pass the obstacle. There are three ways for robot to pass obstacle:

- There is only a side exist obstacle on robot walk path. That is walk top left corner when A-B
- There are obstacles on both side of walk path
- The walk path is consists of both A and B, that is to say some sections are first type path, others are second type path

Structure artificial fish-swarm model:
Structure first path artificial fish model: Shown as picture, initial position A, robot need to come round obstacle to arrived at B. There are two ways to bypass obstacle. One is walks outer line that is the walk route only one side has obstacle. To get to B point, it must across radial L_1 (equality: x = 2(y>10.8)) and L_2 (equality: x = 4(y>10)). So the path of robot walks outer line are connect point A and P_1 which on radial L_1, P_1 and P_2 which on radial L_2, P_2 and B, these three segment constitute.
Use mathematic describe as:

$$P_1 = (2+t, 10.8+t) \ t \in [0, +\infty)$$

$$P_1 = (4+r, 10+r) \quad r \in [0, +\infty)$$

It need to confirm the fish if artificial fish is used to hunt for the shortest path. Point P_1 and P_2 express fishes, that is X = (P1, P2) = (x1, y1, x2, y2). L expresses fish food $L = \left|\overrightarrow{AP_1}\right| + \left|\overrightarrow{P_1P_2}\right| + \left|\overrightarrow{P_2B}\right|$.
The distance d between two fishes is:

$$d(X, X') = \| x1 - x1', y1 - y1', x2 - x2', y2 - y2' \|$$

The fish centre X_C is:

$$Xc = \left(\frac{P_{11} + P_{12} + \ldots + P_{1i}}{i}, \frac{P_{21} + P_{22} + \ldots + P_{2i}}{i}\right)$$

There is no enough time to wait myself code fish-swarm algorithm to hunt for the shortest path. So the description is used mathematics.

Structure second artificial fish-swarm model: There is another choice is walk inner line (obstacle exist both two sides). It must through segment S_1T_1 and segment S_2T_2. So the path of A to B is: connection of point A and q1 which on segment S1T1, connection q1 and q2 which on segment S2T2, connection q2 and B, these are three segments are consist of route of A to B. S1, T1, S2, T2 are known point. Use q1, q2 to express them:

$$q1 = S1 + (T1 - S1) * t_1, \ q1 = S1 + (T1 - S1) * t_2$$
$$t1, t2 \in (0, 1)$$

Mathematic description: Artificial fish X = (q1, q2), the quantity of fish $L = |\overrightarrow{Aq_1}| + |\overrightarrow{q_1q_2}| + |\overrightarrow{q_2B}|$, The distance d between two fishes is:

$$d(Xn, Xm) = \| x1_n - x1_m, y1_n - y1_m, x2_n - x2_m, y2_n - y2_m \|$$

The fish centre X_C is:

$$Xc = \left(\frac{q_{11} + q_{12} + \ldots + q_{1i}}{i}, \frac{q_{21} + q_{22} + \ldots + q_{2i}}{i}\right)$$

Artificial fish, the quantity of food, fish centre have confirmed. The shortest path can be worked out if reasonable step, visual scope and crowding factor δ are ruled.

The third type robot is consists of first type and second type. So it can work out the shortest path by the solution of first type and second type if divide third type robot into first type and second type. It is stated no longer.

THE ACHIEVE OF SIMULATION

Program run environment is AMD Sulong dikaryon 2.91 GHz, OS is Windows XP, program executive software is Microsoft Visual C++ 6.0.

The shortest path of type a method: At first, we supposed type A is segment from initial position (1, 7) to destination 1(5, 12.5). It can discuss with two ways.

One is walk outboard (outer line); other is inner line which the components are object M, object N and object H. It will through two points: P1 and P2. P1 and P2 need artificial fish to confirm the most optimal position.

The parameter of artificial fish is: artificial fish m = 50, visual scope Visual = 0.15, the largest step length step = 0.5, crowding factor δ = 9, iterations is 100, the initial value of artificial fish is any value in reasonable range.

Operation artificial fish-swarm with MATLAB map can get the result as Fig. 4.

The shortest path of type B method: Supposed that type B is segment from initial position (1, 7) to destination 2(9.8, 14). It can discuss with three ways.

One is walk outer line of object M (path 1, shown as path 1 of Fig. 5). One is third type path which consists of object M, object N, object H (path 2, shown as path 2 of Fig. 5). The last is shown as path 3 of Fig. 5.

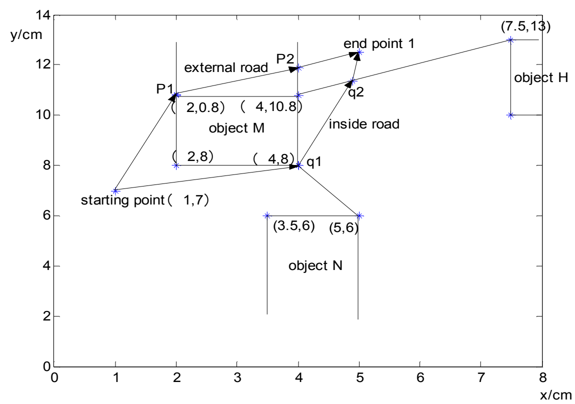

Fig. 4: A type path MATLAB simulate chart

Every point coordinates (unit/cm) and the length of path (unit/cm) is: Inner line path = q1 (4.008400, 7.983199) and q2 (4.894928, 11.362526), Outer line path = P1 (2.000000, 10.812200) and P2 (4.000000, 11.900200), Path length = 7.384047; From the experiment, the robot walk inner line is the shortest path: Start→P1→P2→ destination 2, path length is 7.384047 cm

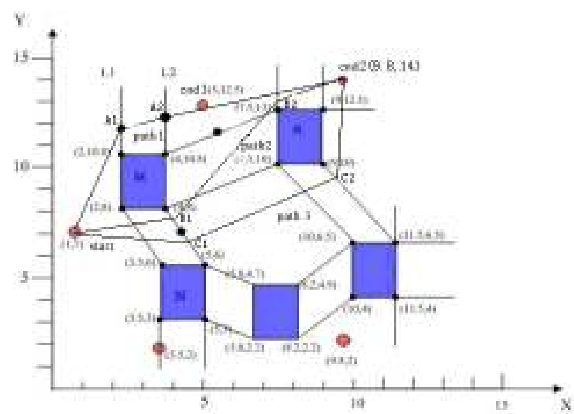

Fig. 5: The robot class B path obstacle avoidance method figure

Optimized path length (unit/cm) and coordinates (unit/cm): Path 1 = A1 (2.000000, 10.858200) and A2 (4.000000, 11.737200), Total path length = 12.396099, Path 2 = B1 (4.015153, 7.969695) and B2 (7.500000, 13.056652), Total path length = 11.819330, Path 3 = C1 (4.057100, 7.885800) and C2 (9.021250, 9.970250), Total path length = 12.671176; From the experiment, the robot walk path 2 is the shortest path: Start→B1→B2→destination 2, path length is 11.819330 cm

The path 1 of artificial fish is X1 = (A1, A2), food is the total length of path. The path 2 of artificial fish is X2 = (C1, C2), food is the total length of path. Artificial fish distance d and centre XC are formulation fit with 3.2 th chapter. It is stated no longer.

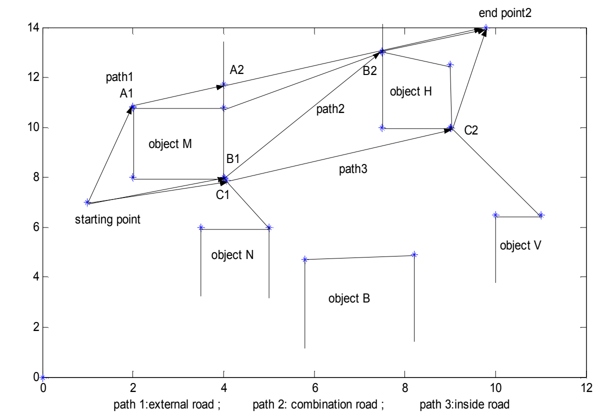

Fig. 6: B type path MATLAB simulate chart

The parameter of artificial fish is: artificial fish m = 50, visual scope Visual = 0.15, the largest step length step = 0.5, crowding factor δ = 9, iterations is 100, the initial value of artificial fish is any value in reasonable range. Mapping result with MATLAB is shown as Fig. 6.

CONCLUSION

Although come up with artificial fish-swarm very early, previous researches are localized. It does just optimize the algorithm main to gain the precise astringency path. Most artificial fish can near around the optimal value. The astringency of robot walk path is more precise. So we choose improvement fish-swarm algorithm that is increase the search surrounding environment times of foraging behavior. It is gets rather improvement of fish-swarm algorithm precision to foraging behavior. But there is little difference on as astringency precise. On the optimizing of robot path, there isn't obvious difference in these two algorithms as the issue is rather simple. However, there is evident distinction on these two astringency precisions of search function s' maximum problem. Improved foraging behavior fish-swarm algorithm astringency is more precise.

ACKNOWLEDGMENT

The authors wish to thank the helpful comments and suggestions from my teachers. This study is supported by the authors are highly thankful for the financial support of National Defense Basic Research Project (B3720110008) and Guangxi Autonomous Region Education Department General Project (200103YB137) and Hechi College of key projects (2010YBZ-N001).

REFERENCES

Barili, A., M. Ceresa and C. Parisi, 1995. Energy-saving motion control for an autonomous mohile rohot. Proceedings of the IEEE International Symposium on Industrial Electronics, Pavia, Italy, pp: 674-676.

Brooks, R., 1986. A robust layered control system for a mobile robot. IEEE J. Robot. Autom., 2(1): 4-23.

Brooks, R. and M. Kaupp, 2007. ORCA: A Componment Model and Repository. In: Brugali, D. (Ed.), Software Engineering for Experiment Robotics. Springer, Berlin/Heidelberg, pp: 231-251.

Chong, H.K. and K.K. Byung, 2005. Energy-saving 3-step velocity control algorithm for battery-powered wheeled mobile robots. Proceedings of the 2005 IEEE International Conference on Robotics and Automation, Barcelona, Spain, pp: 1-6.

Huang, Y., D.B. Sun and Y.Q. Qin, 2006. Path planning of mobile robot based on particle swarm optimization algorithm. J. Ordn. Ind. Autom., 25: 49-50.

Li, X.L. and J.X. Qian, 2003. Studies on artificial fish swarm optimization algorithm based on decomposition and coordination techniques. J. Circ. Syst., 8: 1-6.

Nie, L.M. and Y.Q. Zhou, 2008. Path planning of robot based on artificial fish-swarm algorithm. J. Comp. Eng. Appl., 44: 48-50.

Vasilyev, A., 2002. Synergetic approach in adaptive system. MA Thesis, Transport and Telecommunication institute, Riga, Latvia.

Wang, X.Y., J.H. Yan and Y. Qin, 2009. oenergy optimization strategy of two-wheeled self balanced robot based on improved genetic algorithm. J. Jilin Univ. Eng. Technol., 39: 830-835.

Wei, Z., 2012. An autonomous low cost mobile robot system based on particle swarm intelligent path planner. Int. J. Adv. Comp. Technol., 4: 141-148.

Xie, W., J. Ma and M. Yang, 2010. Agent-oriented architecture for Intelligent service robot. Proceedings of the 8th world Congress on Intelligent Control and Automation, pp: 5964-5967.

Xu, H.L., X.R. Xie and J. Zhuang, 2010. Global time-Energy optimal planning of industrial robot trajectories. J. Mech. Eng., 46: 20-25.

Zheng, S. and H. John, 2006. On finding approximate optimal paths in weighted regions. J. Aigorit., 58: 1-32.