Research on Global Path Planning Method of Mobile Robot Based on BAS

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Abstract. In this paper, a path planning algorithm based on the beetle antennae search (BAS) is presented, which can effectively improve the speed, obstacle avoidance and environmental adaptability of the robot path planning. The distance between the beetle and the target point is the fitness function, and the changing step size is to avoid the local optimization. According to compare random coordinates of the beetle’s left and right antennae, the direction of walking is determined to plan the better path in the static environment. The obstacle avoidance is judged by whether the beetle’s position and walking trail are in the effective area. Multiple beetles are set at each path point, and the optimal direction which approaches the theoretical optimal path, is chosen after comparing with every beetle’s trail. A large number of results of the experiments based on RRT and BAS algorithm indicate that BAS algorithm is more capable of searching its path and avoiding obstacles. Even in a complex environment, compared with other algorithms, BAS is more likely to rapidly plan an optimal path which can successfully avoid obstruction.

1. Introduction
Path planning is significant in the research of Mobile Robot Control and is fundamental to task completion [1]. Path planning means that the robot which is compatible with certain restriction conditions and evaluation conditions can find out an approximate optimal or suboptimal path from the starting point to the terminating point and avoid the obstacles. According to environmental information known by the robots, path planning has been divided into global path planning based on the all-known environment information and local path planning based on unknown or partly known environment information [2]. At present, there are many common global path planning methods for mobile robots, such as traditional grid method and artificial potential field method [3]. Although grid method is suitable for global path planning, when the environmental space increases, the required storage space soars, the computational efficiency and the decision speed decreases. On the other hand, the artificial potential field method is likely to cause local optimum and deadlock phenomenon. With the development of intelligent control technology, algorithms such as A* algorithm, genetic algorithm (GA), ant colony algorithm (ACA), particle swarm algorithm (PSO) and rapidly-exploring random tree algorithm (RRT) have appeared [4-8]. When solving the problems of robots planning the paths, the artificial potential field method, the neural network method and the genetic algorithm need to model the obstacle in definite space. However, these methods are always inefficient in practice. RRT has the characteristics of large randomness, strong obstacle avoidance ability, but it is weak in real time and inefficient in search. Compared with other algorithms, BAS [9] only requires one individual
and can replan the path by observing every step whether bumping into the obstruction or not. Therefore, there’s no need modeling and analyzing on the current environment in advance, which greatly decrease the computational complexity while largely increase the efficacy.

BAS used in this paper is a heuristic search algorithm. The algorithm has the features of strong robustness, rapidity, randomness and no need of preprocessing. At the same time, it can effectively solve the problem of path planning in high dimensional space and complex environment with simple algorithm. This intelligent optimization algorithm can realize optimization without knowing the specific form and gradient information. This paper uses the BAS algorithm to do research on the path-planning of the mobile robots, with the emphasis on the simulation analysis.

2. The description of BAS algorithm

2.1. Basic principle of the algorithm

Bionics: The beetle does not know where the food is when it is preying, but it can adjust the movement by feeling the smell of food. Beetle has two long antennae, when the left antennae detects a higher concentration of odour, the beetle would turn to the left, otherwise, it would turn to the right until the food is found [10]. The simplified model diagram of foraging for a beetle is shown in figure 1.

![Figure 1. Simplified model diagram of foraging for a beetle.](image)

The hypothesis of a simplified model of a beetle:

- The head orientation of the beetle is arbitrary and can be represented by a random vector.

\[ b = \text{rands}(k, 1) \]

(1)

The normalization follows as:

\[ \tilde{b} = \frac{\text{rands}(k, 1)}{\|\text{rands}(k, 1)\|} \]

(2)

where \( \text{rands}(\cdot) \) represents a random function and \( k \) represents the spatial dimension.

- Position of the right and left antennae of the beetle.

\[
\begin{align*}
    x_i &= x' + d_0 \cdot \frac{\tilde{b}}{2} \quad (t = 0, 1, 2, \cdots, n) \\
    x_i &= x' - d_0 \cdot \frac{\tilde{b}}{2}
\end{align*}
\]

(3)

where \( x_i \) and \( x_r \) represent the antennae coordinate; \( x' \) represents the centroid coordinate of the \( t \) iteration and \( d \) represents the distance between two antennae.

- The fitness function of the path planning which needs optimizing is used to calculate the fitness value of both left and right antennae.

\[
\begin{align*}
    f_i &= f(x_i) \\
    f_i &= f(x_r)
\end{align*}
\]

(4)

- Update the position of the beetle.
Making comparison between the left and right values, if \( f_l \) is less than \( f_r \), the beetle moves step to the direction of left antennae and vice versa.

\[
x^{t+1} = x^t - \delta^t \cdot h \cdot \text{sign}(f(x) - f(x))
\]

(5)

where \( \delta^t \) is the step size of \( t \) iteration and \( \text{sign}(\cdot) \) is symbolic function.

2.2. Environmental modeling
The working environment of the robot is two-dimensional space. During the operation of the robot, the obstacles are stationary and the size remains unchanged. The images are drawn according to the actual environment, in which shapes in black are the obstacles and the white area is the passable place. The shapes in black are larger than the actual obstacles, trying to make the environmental model consistent with the real situation, so that the robot can move smoothly in the planned path. After the image is transferred into a binary image, the starting and ending points of the robot can be set at the feasible interval.

2.3. Algorithm execution steps
The specific flow chart of BAS path planning is demonstrated as shown in figure 2:

\[\text{Environmental modeling} \rightarrow \text{Initialization parameters} \rightarrow \text{Update the right and left antennas position of the beetle} \rightarrow \text{Antennas are located in block area?} \rightarrow \text{Update the position of the beetle} \rightarrow \text{The path is in the blocking area?} \rightarrow \text{Multiple beetles looking for optimized direction} \rightarrow \text{Update search step size and antennas spacing} \rightarrow \text{Calculate the fitness value} \rightarrow \text{That satisfies the end condition?} \rightarrow \text{Get a better path} \]

Figure 2. BAS path planning process.
The steps of BAS path planning follow as:

- Modeling is on the basis of the working environment of the robot.
- Detailed parameters of BAS algorithm are to set: step (δ), the distance between two antennae (d), number of iterations (n), initial position (x₀) and spatial dimension (k).
- Set the initial position of the beetle as the starting point and determine the coordinates of the left and right antennae to ensure that it is within the effective area of the environmental model.
- Calculate the value of the two antennae coordinates with fitness function and then compare the value. If the fitness value of the left antennae is smaller than that of the right antennae, then the position of the direction of left antennae is the next position of the beetle and vice versa.

Fitness function:

\[
\text{fitness}(x', y') = \sum \sqrt{(x - x')^2 + (y - y')^2}
\]

where \((x, y)\) is the coordinates of the end point of the path and \((x', y')\) is the position of beetle at \(t\) iteration.

- During the update the position information of beetle, if the search position exceeds the set space range, it will select the set space range as the position information.
- The position of the right and left antennae is checked whether it is in the feasible region. If not, the coordinates of the left and right antennae need to be obtained again. The path is judged whether it is valid according to the constraint conditions. If not, it needs to be reinitialized until the path is guaranteed to be valid.
- This paper has set a number of beetles at each planned position and each of which will randomly search for one direction and select the optimal direction by comparison.
- When the beetle reaches a certain distance from the target point or the maximum number of iterations, the beetle exits the loop and a better path will be displayed in the figure.

3. Simulation analysis of path planning based on BAS algorithm

Under the two circumstances of constant and variable step size, the path planed by the BAS algorithm and the number of iteration are demonstrated in figure 3 and figure 4:

![Figure 3. BAS path planning based on constant step size.](image)

It can be seen from figure 3 and figure 4 that the path planning can be completed after about 25 generations. If the step size is unchanged, the robot will move in the same length as the step size, which will largely deviate from the shortest path. While in the case of a variable step size, with the gradually reduced step size the robot will be carefully searched near the target point, so that the obtained path is closer to the optimal value.

This paper puts 30 beetles at each planned location. Multiple beetles are looking for their next landing spot at the same time. The beetle that ran into obstacles is abandoned. It is more efficient to re-search the path than one single beetle does. The path planning based on 30 beetles and the number of iteration are shown in figure 5.
In figure 5, compared with one single beetle, the planned path of multiple beetles is more stable, so that a better path can be selected.

In order to test whether BAS algorithm is superior to other intelligent optimization algorithms in robot path planning, comparisons of robots’ path-planning based on RRT and BAS algorithms are made, in which the starting point and the environment are guaranteed to be the same. See figure 6.

According to the figure 5 and figure 6, both algorithms can successfully avoid the obstacles and plan a path. The path planning based on RRT algorithm will randomly extend the tree node until the new node covers the target point or enters the region containing the target point. It will form a path consisting of random tree nodes between the starting point and the target point. However, many redundant nodes will be generated. The path planning based on BAS algorithm can correct the direction step by step according to the fitness value, so that the time of the algorithm is reduced and the planned path is closer to the optimal one. The time taken by RRT algorithm and BAS algorithm to complete the path planning is demonstrated in table 1:
Table 1. Program running time comparison table based on different algorithms.

| Algorithm                                      | Total time (s) | Self-use time (s) |
|------------------------------------------------|----------------|-------------------|
| RRT algorithm                                  | 4.174          | 1.883             |
| BAS algorithm with constant step size          | 2.618          | 0.479             |
| BAS algorithm with variable step size          | 2.516          | 0.425             |
| BAS algorithm based on multiple beetles         | 2.636          | 0.616             |

By comparing the runtime of the programs based on different algorithms, not only the total time of the program but also the algorithm itself, the BAS algorithm runs 1.5s faster than the RRT algorithm. Also, the difference in the total time of the BAS algorithm with variable and constant step size is of little difference. Multiple beetles take a little more time than one single beetle.

In conclusion, the BAS algorithm based on multiple beetles can plan a better path in a short time, reflecting that the BAS algorithm has good applicability in path planning.

4. Conclusion
In this paper, a new algorithm of path planning for the robots based on the beetle antennae search is proposed. The complexity of this algorithm is not much affected by environmental obstacles. Simulation results demonstrate that the proposed algorithm has strong environmental adaptability and can rapidly plan a path and even though in a complex case of obstacles. On this basis, the planned path is not prone to fall into local optimum, and the iteration speed is fast. However, there are also some deficiencies. For example, the optimal solution of the path needs to be further improved.

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