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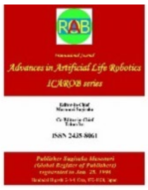

Research Article

A Review of Research on Autonomous Obstacle Avoidance Algorithms for Intelligent Vehicle

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ABSTRACT

This paper systematically summarizes the current research status and development of obstacle avoidance algorithms. The characteristics of the unmanned vehicle obstacle avoidance algorithms are classified into traditional and intelligent algorithms. Based on the above classification, the representative research results in recent years are introduced, focusing on the advantages and disadvantages of various types of obstacle avoidance algorithms. The future development trend of the unmanned vehicle obstacle avoidance algorithm is also prospected in order to provide some ideas for the subsequent research.

1. Introduction

The intelligent vehicle belongs to the category of wheeled robots, which is an integrated system with functions such as environment perception, obstacle avoidance, and path planning [1]. The safe driving of intelligent vehicles mainly relies on their obstacle avoidance systems to achieve. Smart car obstacle avoidance refers to the smart car sensing static and dynamic obstacles that hinder its passage through sensors during the driving process. After obtaining obstacle information, the vehicle is able to follow certain methods for effective obstacle avoidance and finally reach the target point.

At present, the algorithm research in the field of autonomous obstacle avoidance has achieved certain results. In this paper, the existing algorithms are classified into traditional algorithms and intelligent algorithms according to the applicable environment, and they are elaborated and summarized respectively.

2. Traditional Obstacle Avoidance Algorithms

The more classical methods of traditional obstacle avoidance include visual graph method, grid method, artificial potential field method, virtual force field method, etc.

2.1. *Visual graph method*

The visual graph method, proposed by Lozano-Perez and Wesley in 1979, is the classical algorithm for global motion planning of unmanned vehicles. In the visual graph method, the unmanned vehicle is described by points and the obstacles are described by polygons, and the starting point, the target point and the vertices of the polygon obstacles are combined and connected. It is required that the line between the starting point and each vertex of the

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obstacle, between the target point and each vertex of the obstacle, and between each vertex of the obstacle and the vertex cannot cross the obstacle, i.e. the line is "visible". The vehicle then uses some optimization algorithm to search for the optimal path from the starting point to the target, and then the shortest path from the starting point to the target is obtained by accumulating and comparing the distances of these lines. The visual map method can find the shortest path, but due to its lack of flexibility, the time to search for the correct obstacle avoidance path will be long when there are many obstacles. At the same time, the visual map method has difficulty in avoiding circular obstacles, thus limiting its practical application.

2.2. *Grid method*

The grid method was proposed by W.E. Howden in 1968. It is a physical model in the shape of a grid to represent the likelihood of an obstacle's appearance. The size of the raster affects the amount of environmental information stored and the length of time. The larger the raster division, the smaller the storage of environmental information, the lower the resolution, the less effective obstacle avoidance in complex environments, and the shorter the search time. The smaller the raster division, the larger the storage of environmental information, the higher the resolution, the better the obstacle avoidance in complex environments, and the longer the search time.

Through the raster method, intelligent vehicles can achieve accurate navigation and make effective obstacle avoidance maneuvers in static environments. However, it has certain requirements on the size of the working area. If the working area is too large, the number of grids will increase sharply and the computation will increase, which is not conducive to obstacle avoidance in real-time dynamic environment.

2.3. *Artificial potential field*

The artificial potential field was originally proposed by Khatib in 1985 and has since been widely used in path planning for mobile robots such as unmanned vehicles. Its basic idea is to consider the motion of an unmanned vehicle in its surroundings as the motion of an unmanned vehicle in an artificially created virtual force field. In the virtual force field, the target point generates a gravitational force that guides the vehicle towards the target point and the obstacle generates a repulsive force that prevents the vehicle from colliding with the obstacle. The motion of the vehicle is controlled according to the combined forces of gravity and repulsion to produce a collision-free optimal path.

Artificial potential field method has the advantages of high real-time, rapid response and simple calculation. However, if the combined force at a point during the vehicle motion is zero, the unmanned vehicle cannot bypass that point, and this presents a local minimum problem. And when the target is surrounded by obstacles, the path cannot converge and the unmanned vehicle is also unable to reach the target point.

3. Intelligent Obstacle Avoidance Algorithm

Intelligent obstacle avoidance algorithms are generally stochastic search algorithms based on biological intelligence or physical phenomena, commonly known as fuzzy logic algorithm, genetic algorithm, neural network methods and ant colony algorithm[1].

3.1. *Fuzzy logic method*

The fuzzy logic algorithm focuses on designing a library of fuzzy control rules based on human driving experience[2]. The algorithm takes the information obtained from the sensors as input and after fuzzy inference yields the desired output of the vehicle, which is generally the speed and deflection angle of the vehicle. Because the kinematic model of the intelligent vehicle is nonlinear and strongly coupled, and the fuzzy control obstacle avoidance algorithm does not depend on the accurate motion model of the controlled object, the use of fuzzy control obstacle avoidance algorithm is also one of the frequently used methods in research.

For fuzzy control of unmanned vehicle obstacle avoidance, the key issue is to establish a suitable fuzzy controller. The fuzzy controller is shown in Fig.1.

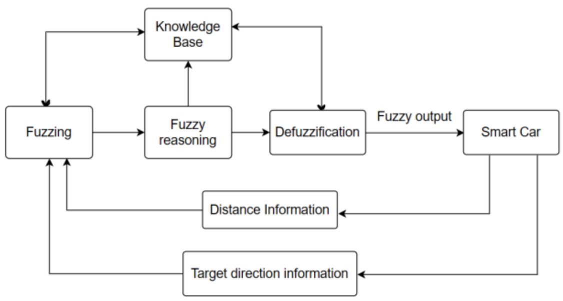

Fig.1 Fuzzy controller for obstacle avoidance

There are 3 main points in establishing a suitable fuzzy controller.

(1) Substitution of linguistic variables for mathematical variables.

(2) Describe the relationships between variables using fuzzy control condition statements.

(3) Describing complex relationships with fuzzy algorithms.

However, since fuzzy rules are pre-defined by experience and the number of fuzzy rules grows exponentially with the number of inputs[3]. Therefore, the fuzzy logic obstacle avoidance algorithm cannot learn autonomously and lacks the flexibility of real-time obstacle avoidance.

3.2. *Genetic algorithms*

Genetic algorithms are a method for searching for optimal solutions[4]. It is an intelligent algorithm that simulates the evolutionary principles of biology and achieves species evolution through evolution and genetic variation. Genetic algorithm-based obstacle avoidance methods are an effective intelligent algorithm in the field of autonomous obstacle avoidance research for unmanned vehicle[5].

The genetic algorithm treats all path points as a population and uses binary coding to encode each path point, then selects the path points according to the fitness function and performs combinatorial crossover and mutation with the help of genetic operators, gradually evolving to produce increasingly optimized approximate solutions. At the same time, global path planning is combined with local path planning in the planning process and corresponding obstacle avoidance strategies are proposed depending on the type of collision between the unmanned vehicle and dynamic obstacles. The algorithm can be well integrated and improved with other intelligent algorithms, and can take full advantage of iterative evolution. The initialized population generation method and the introduction of genetic operators increase the flexibility of the search process and have better global optimal path solving capability. However, the calculation speed of the algorithm is slow, the efficiency of global path search is relatively low, there are too many path inflection points, and the algorithm also generates some meaningless populations during iterative evolution, which makes the subsequent calculation less efficient and is not suitable for real-time obstacle avoidance. The genetic algorithm based obstacle avoidance process is shown in Fig.2.

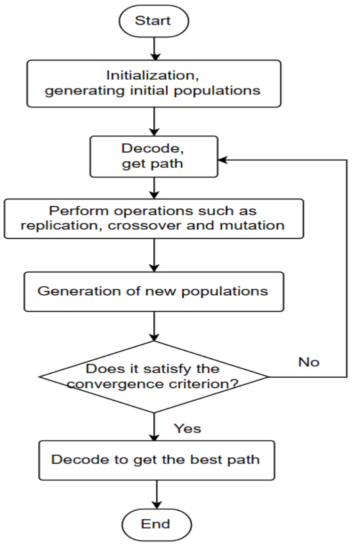

Fig.2 Genetic algorithm based obstacle avoidance process

3.3. *Neural network*

A neural network is a mathematical or computational model that mimics the structure and function of a biological neural network[6]. Neural network algorithms are more flexible in fuzzy rules and affiliation determination. The neural network can consider the information data collected by the sensors as the input and the motion direction of the next position of the intelligent vehicle as the output, and eliminate redundant and opposing samples to get the final sample set. The neural network has simple learning rules and strong autonomous learning ability, but if the data obtained from the sensors are incomplete, the neural network cannot proceed and has poor generalization ability, so it is not successful in obstacle avoidance planning applications at present. The structure of the neural network obstacle avoidance system is shown in Fig.3.

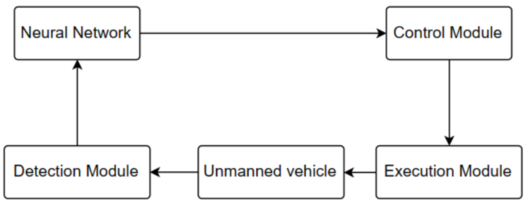

Fig.3 Neural network obstacle avoidance structure

3.4. *Ant colony algorithm*

The ant colony algorithm is an intelligent optimization algorithm proposed by Dorigo et al. Bionomists have discovered that ants transmit information between individuals through a substance called pheromone, which the ants can sense to guide their direction. The basic principle of the ant colony algorithm is shown in Fig.4.

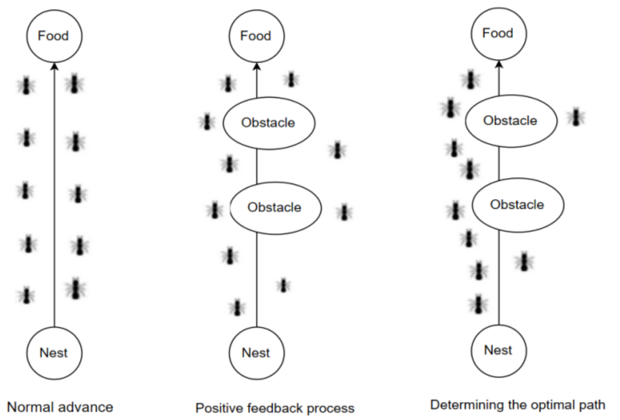

Fig.4 Principle diagram of ant colony algorithm

The principle of the algorithm is a path search system based on a positive feedback mechanism. The first ants that first set out in the nest randomly choose a path around the obstacle with equal probability, and the individual ants located on the shortest path will inevitably return first. And this ant will release a certain concentration of pheromones in the area it passes through to attract other ants to this path. This allows the total number of ants passing through the shortest path for a fixed interval of time to be greater than on the other paths, resulting in the highest pheromone concentration on the shortest path as well. This obviously increases the probability that ants looking for food behind will choose that shortest path, thus creating a good positive feedback. As a result, the pheromone concentration on the optimal path will accumulate more rapidly, and eventually the ant colony will gather on the optimal path.

The ant colony algorithm has the advantages of positive information feedback mechanism, strong robustness and easy parallel implementation. However, in the initial stage if the pheromone is missing or the path size is too large, it will lead to too slow path planning.

4. Conclusion

The article presents a comprehensive analysis and description of the main traditional and intelligent algorithms in the field of unmanned vehicle obstacle avoidance. Based on each algorithm's own principles, different algorithms will behave differently in different environments. Traditional algorithms are highly effective but of low practicality, while intelligent algorithms converge quickly but suffer from the problem of falling into local optima in more complex environments. Therefore, in practical situations, to perform accurate, safe and fast obstacle avoidance relying only on a single algorithm is limited. Therefore, how to overcome the limitations of existing algorithms and effectively integrate the advantages between them is the focus of future research in the field of unmanned vehicle obstacle avoidance.

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Authors Introduction

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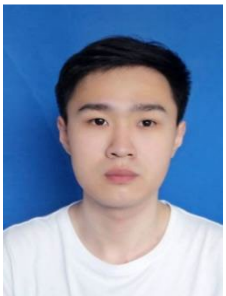

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