An Overview of Obstacle Avoidance Methods for Unmanned Vehicles

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Abstract

Autonomous obstacle avoidance is one of the popular research elements in the field of intelligent unmanned vehicles, and it is a key technology to realize the automatic travel of intelligent unmanned vehicles. This paper introduces the traditional algorithms and intelligent algorithms related to autonomous obstacle avoidance, and analyze the advantages and drawbacks of the corresponding algorithms. The development of the corresponding control strategies is also summarized and summarized in order to provide some reference for the research on obstacle avoidance of intelligent unmanned vehicles.

Keywords: avoiding obstacles, unmanned vehicle, control strategy, algorithm

1. Introduction

Obstacle avoidance path planning for intelligent unmanned vehicles is an important and challenging task that plays a crucial role in the operation of unmanned vehicles [1]. The obstacle avoidance system of the unmanned vehicle uses the sensors installed in the vehicle and the sensory information provided by the outside world to sense the speed, acceleration, position, status and other information about itself and the outside environment during the vehicle's travel. Then, by calculating and analyzing relevant information, we make decisions for safe vehicle driving and control the actuator to realize automatic vehicle driving.

Unmanned vehicles will encounter static or dynamic obstacles in the course of travel, at which time relevant algorithms and autonomous obstacle avoidance strategies need to be introduced to achieve real-time, accurate autonomous obstacle avoidance and ensure the safe operation of the vehicle.

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 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 the search time is long and inflexible, and it is troublesome to reconstruct the visual map once the starting point and target point of the unmanned vehicle are changed. The visual map method is applicable to polygonal obstacles, but not to circular obstacles. The tangent diagram method and the Voronoi diagram method improve the visual diagram method. The tangent map method uses the tangent of the obstacle to represent the arc, so the map of the shortest path from the starting point to the target point, and the unmanned vehicle must almost walk close to the obstacle. The disadvantage is that the possibility of unmanned vehicles colliding with obstacles can be high if position errors arise during control. The Voronoi diagram method represents the arc by a path that is as far away from obstacles and walls as possible. As a result, the path from the starting point to the target point will grow, but with this type of control, the unmanned vehicle will not encounter obstacles even if position errors are generated.

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 grid method uses the basic element as the minimum grid granularity to rasterize the map, and the basic element in the free zone takes the value of 0, in the obstacle zone or contains the obstacle zone is 1, so that a map can be used for path planning in the computer. When each grid is given a passage factor, the path planning problem becomes a problem of finding the optimal path between two grid nodes on the grid network. In a grid map, the size of the grid affects the amount of environmental information stored and the length of time. The smaller the grid division, the greater the storage of environmental information, the higher the resolution and the better the obstacle avoidance in complex environments, but the longer the computation time.

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.

The driving paths planned by applying an artificial potential field are generally smooth and safe, with simple algorithms and good real-time performance. But the algorithm also has some drawbacks. For example, when there is an obstacle near the target point, the repulsive force is much greater than the gravitational force and the vehicle will have difficulty reaching its destination. When the gravitational and repulsive forces at a point are exactly equal in magnitude, the combined force on the unmanned vehicle is zero, i.e. it is caught in a local minimum problem. A great deal of research has been carried out by scholars in various countries to optimize these issues.

The virtual force field is a real-time obstacle avoidance algorithm for unmanned vehicles that combines the grid method with an artificial potential field. The VFF algorithm is a local obstacle avoidance algorithm that uses a grid to represent the environment and a force field method to control the unmanned vehicle.

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

Instead of simplifying the actual situation and thus building a mathematical model as in classical control theory, fuzzy control uses human experience and decision making to reason with the corresponding fuzzy logic and describes the entire time-varying control process in a language with fuzziness. The fuzzy logic obstacle avoidance algorithm is an intelligent obstacle avoidance algorithm based on real time sensing information and reference to human driving experience, which achieves local path planning by building a fuzzy control rule base to obtain planning information [2]. The method develops corresponding fuzzy control rules based on information such as the angle between the direction of motion of the dynamic obstacle and the unmanned vehicle, the time of collision and the position of the collision point on the obstacle.

For fuzzy control of unmanned vehicle obstacle avoidance, the key issue is to establish a suitable fuzzy controller. The fuzzy controller is mainly responsible for the fuzzification of sensor sensing information, the operation of fuzzy relations, fuzzy decision making and the non-fuzzy processing of the obstacle avoidance decision results, and thus intelligently controls the obstacle avoidance behavior of the unmanned vehicle. The fuzzy controller is shown in Fig.1.

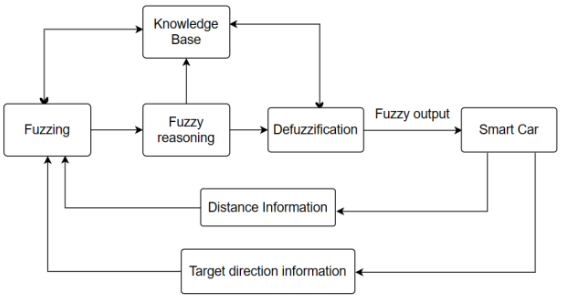

Fig.1 Fuzzy controller for obstacle avoidance

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.

Fuzzy logic obstacle avoidance algorithms have the disadvantage of not being able to learn on their own and being inflexible. This is because fuzzy rules are pre-defined by experience and do not change with the input of unknown environmental information, and the number of fuzzy rules increases exponentially with the number of inputs [3].

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 vehicles [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 effectively guide unmanned vehicles to achieve obstacle avoidance in dynamic environments and obtain collision-free optimal or sub-optimal paths. The genetic algorithm based obstacle avoidance process is shown in Fig.2.

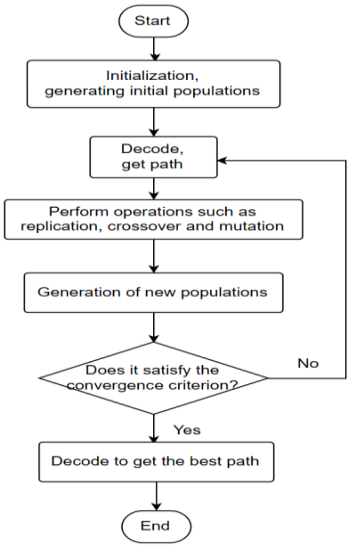

Fig.2 Genetic algorithm based obstacle avoidance process

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 networks consist of a large number of artificial neurons linked together for computation. In most cases artificial neural networks can change their internal structure based on external information and are an adaptive system. Artificial neural networks are typically optimized by a mathematical statistics-based type of learning method, a nonlinear statistical data modeling tool that can model complex relationships between inputs and outputs.

Neural network obstacle avoidance path planning methods tend to build a neural network model about the travel path of an unmanned vehicle from an initial position to a target position. The model input is the sensor information and the motion direction of the previous position or the previous position of the unmanned vehicle, and after the model is trained, the motion direction of the next position or the next position of the unmanned vehicle is output. The structure of the neural network obstacle avoidance system is shown in Fig.3.

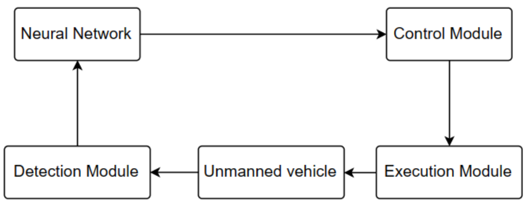

Fig.3 Neural network obstacle avoidance structure

There is now another emergence of building dynamic neural network-based obstacle avoidance algorithms for unmanned vehicles. The dynamic neural network can automatically adjust its structure according to the complexity of the state of the unmanned vehicle environment and realize the mapping relationship between the state of the unmanned vehicle and its obstacle avoidance action in real time, which can effectively reduce the computing pressure of the unmanned vehicle information processing system.

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.

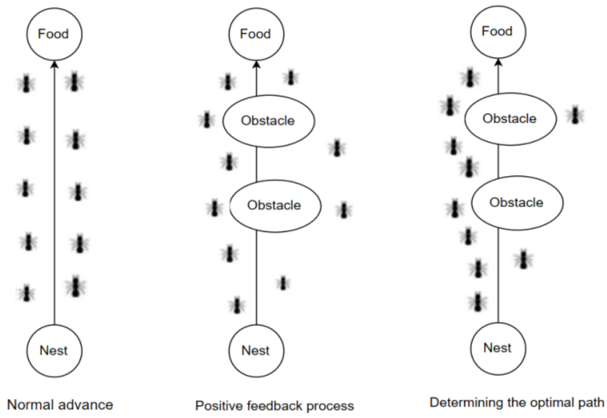

Fig.4 Principle diagram of ant colony algorithm

When an ant finds food, it will release a volatile secretion, or pheromone, into the environment to attract other ants to come, so that more and more ants will pass this path. As more ants pass on the path, the more pheromones are left behind and the more likely it is that new ants will choose this path, which is a positive feedback process. Some ants do not repeat the same path as others, they will find another way, and if the other path is shorter than the original one, then, gradually, more ants are attracted to this shorter path. Finally, after a period of running, the colony can always find the shortest path between the food source and the nest. The ant colony algorithm is to simulate the foraging behavior of ant colony through continuous iteration to complete the process of finding the shortest and 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. Therefore, when using the ant colony algorithm for unmanned vehicle obstacle avoidance path planning, the grid method is usually used first to model the environment of obstacles, and then the global obstacle avoidance path planning is performed using the ant colony algorithm.

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. Both traditional and intelligent algorithms can solve the problem of unmanned vehicle obstacle avoidance to some extent, and each algorithm has its advantages and limitations.

However, with the development of driverless technology, the complexity of its application scenarios is increasing. 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, effectively integrate multiple algorithms, build on their strengths and avoid their weaknesses, and achieve path planning with completely unknown obstacle information is the focus of future research in the field of unmanned vehicle obstacle avoidance.

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