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An In-Depth Summary of Mobile Robot Navigation Protocols

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A B S T R A C T

A mobile robot is a self-driving machine that employs sensor-actuator control strategies to navigate anywhere intelligently. The autonomous mobile robot is finding more and more uses in domains including business, science, transportation, military, and other sectors of society. The mobile robot carries out a variety of jobs, including material handling, interplanetary exploration, disaster relief, patrolling, and rescue operations. It is therefore necessary to develop a smart mobile robot that can move independently through a variety of static and dynamic surroundings. The various researchers have used a variety of strategies for mobile robot navigation and obstacle avoidance. The study of intelligent navigation algorithms that can guide a mobile robot independently across both static and dynamic surroundings is the main subject of the current paper.Autonomous skills for mobile robots are advantageous. It enables the removal of human operators, which may be advantageous from an economic and safety standpoint. Path planners are typically necessary for autonomy because they allow the robot to carefully consider how to go from one area to another. Given the plethora of methodologies that are available in the literature, finding the path planning algorithm that best fits the demands put forth by users can be difficult.

Keywords:Robot Navigation, Genetic Algorithm, Neural Networks

1. Introduction

For mobile robots, autonomous navigation is a valuable feature. It lessens the need for human intervention, which helps. However, it also involves a lot of work or issues that need to be resolved, including path planning. Finding the most effective strategy to move a robot from its current state to the desired one is the task at hand. The goal and the starting location, for instance, could each represent one of the two states. This course of action takes the form of a path, which is sometimes referred to as a route in other works. The route is used to direct the robot to the target state. Given the available space for the robot to move in, there may be a variety of feasible routes. The overarching objective of path planning strategies is to find the best path or, at the very least, an acceptable approximation of it. In this context, the term "best path" refers to the optimum path, meaning that it is the path that results from minimising one or more subjective optimisation functions. For instance, this route can be the one that takes the least time. This is crucial for missions like those in the search and rescuing industry [1] because victims of a disaster may request assistance in life-or-death circumstances.

The energy of the robot can be a further optimisation function to take into account. This is crucial in the case of planetary exploration because rovers only have a finite amount of energetic resources at their disposal [2]. The planner's path must also adhere to any limitations that have been set. These might result from the robot's limited capacity to adapt to specific terrains. The types of manoeuvres that can be carried out are restricted by the robot's locomotion and the features of the surrounding terrain. Consequently, the path planner can generate fewer viable paths as a result.A critical task and one of the many processes that ensures movement from a starting location to a destination is the capacity of mobile robots to navigate. Navigation must concentrate on the obstacle avoidance problem in order to stop any potential problems or accidents.

2. Related Work

There are many different path planning strategies in the literature, and this number has grown over time. In light of certain criteria (such as the aforementioned movement restrictions), choosing the best course of action can be difficult. Additionally, as will be detailed below, the bulk of current path planning solutions are not fully covered by the most recent evaluations and surveys on the subject. This is the primary driving force behind the creation of this review paper, which goes into great detail about various path planning categories and introduces pertinent representative references from the literature for each one, concentrating on those algorithms designed for robots that move on top of surfaces (such as the ground, water, etc.).

In the realm of mobile robots, navigation, which may be divided into two categories: global navigation and local navigation, is a crucial task [3]. Prior environmental knowledge should be accessible throughout global navigation. For global navigation, numerous techniques have been established, including the Voronoi graph, Artificial potential field method, Dijkstra algorithm, Visibility graph, Grids, Cell breakdown approach, and others [4-5].

3. soft computing techniques

The following is a summary of the many soft computing strategies used for mobile robot navigation across multiple static and dynamic contexts.

3.1. Fuzzy logic (FL)method

Numerous academics have used the fuzzy logic technique to manage the location and orientation of mobile robots in the environment. An intelligent fuzzy logic controller has been created by Ren et al. [6] to address the issue of a wheeled mobile robot navigating in an uncharted and dynamic environment. Human reasoning, which is based on perception, serves as an inspiration for fuzzy logic systems.Command arbitration is one of the issues with conventional behavior-based navigation systems for mobile robots. Having numerous concurrently executing behaviours creates circumstances where multiple command outputs may be generated. A different command arbitrator will decide which output should be used to control the robot. The robot may travel in an entirely unexpected direction if this strategy is used, and it does not necessarily result in smooth motion control.The benefit of employing fuzzy logic for navigational is that it makes it simple to combine the outputs of different behaviours through a command fusion procedure. An obstacle avoidance behaviour and a goal-seeking behaviour make up the navigation system in this scenario.

The intended path of motion and the sensor array readings serve as the fuzzy controller's inputs. The command fusion method is used to combine the outputs from each behavior's rule base, and a modified defuzzification technique is used to make the results precise. The robot's motion is controlled at the end with great smoothness.The fact that the arbitration procedure used only permits one behaviour to be active at a time is one of the issues with subsumption. Even if this is acceptable in a lot of circumstances, there are instances when a combination of two behaviours is necessary. Consider travelling towards a target while avoiding hazards. Any one of these could be used as a single behaviour. The robot will proceed to its destination with grace as long as no obstructions are found.Still, if an obstruction is found, the robot will steer clear of it thanks to the behaviours for avoiding obstacles. The issue with this is that since the goal position is unknown to the obstacle avoidance behaviour, the robot could be guided in any direction to avoid the obstruction. This may be effective in many circumstances, but there are other instances where it may be preferable for the robot to steer in a direction that brings it closer to its intended path. By integrating the output of the two behaviors—a process known as command fusion—this can be accomplished. The combined output from the path-following behaviour and the obstacle-avoidance behaviour results in a heading that directs the object towards its intended location.Using a fuzzy logic-based framework, the path-following and obstacle-avoidance behaviours are both realised. A set of fuzzy control rules and a fuzzy inference make up each behaviour module. The result of each behaviour is a fuzzy set rather than a clear control value.

To create a clear output value, these sets are subsequently concatenated via a command fusion module and defuzzified (Figure 1). A fuzzy set representing the desired turning direction results from the path-following behaviour, whereas a fuzzy set indicating prohibited turning directions results from the obstacle-avoidance behaviour.

3.2. Neural network t Processing

One crucial method for mobile robot navigation is the neural network (NN). Numerous investigators are using this NN technology, which is inspired by the human brain and used in areas like signal and image processing, pattern recognition, mobile robot path planning, and commerce.The literature review of neural networks and their uses in mobile robotics was presented by Zou et al [7]. To create a reliable path-planning algorithm for the mobile robot, the authors of Xiao [8] coupled the multi-layer feed forward artificial neural network with Q-reinforcement learning. The multilayer neural network controller and proportional integral derivative (PID) controller were used in Rai & Rai[9] design of the Arduino Uno microcontroller-based DC motor speed control system. Using neural network architecture, Patino&Carelli [10] created the autonomous steering controller for a mobile vehicle.

4. Reactive Manoeuvre

The methods described here rely on specifying how the robot will respond to barriers at each instant. A formulation that takes into account the position of present impediments can be used to characterise this reaction. The low computational needs required to produce the reaction, which typically takes the form of a steering or velocity instruction, are a defining characteristic of the various formulation approaches. These methods are often utilised as local planners because this formulation lacks global knowledge. The formulation in issue may be based on the use of fields to address obstacle placement, the detection of obstacle borders to avoid them, or the generation of a velocity command following an assessment of the amount of free space or the speed of moving obstacles.Artificial Potential Fields (APF) and Vector Field Histogram (VFH) algorithms are examples of field approaches. In APF, a robot's motion may be caused by the total of virtual forces that obstacles and other external factors like them generate. As a result, the robot moves further away from the obstacles and avoids running into them because their forces are repulsive . The target point generates an attractive force that causes the robot to move in its direction.

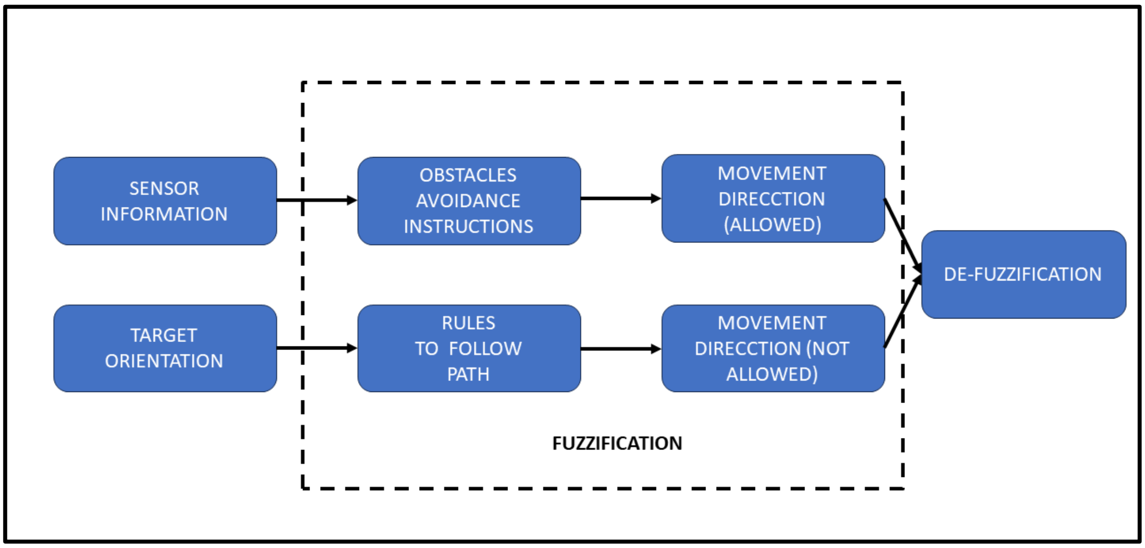

Fig. 1 Navigation Control based on Fuzzy Logic

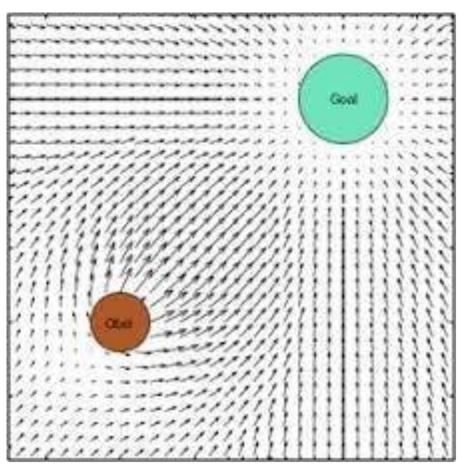

Fig. 2 An Instance of potential Field

5. Geometric navigation

By using a map's coordinates, a robot may go from one location in its environment to another via geometric navigation. The trajectory between two places is a sequence of points the robot must reach in the specified order. The map of the environment is traditionally expressed as a grid of points. The robot's controller must travel to the following point on the course while closing a loop using encoder information on the robot's position (distance and angle). Path planning from a starting point to a finishing point is one of the primary goals of geometric navigation research, and developing an algorithm capable of doing so will help.Although the path-planning task is widely treated in mobile robots, computational capacity has increased exponentially and more complex algorithms can be developed. Algorithms try to find the shortest or fastest path while maintaining safety constraints. Another challenge is to try to get solutions that provide smoother trajectories, trying to imitate the human trajectories.

6. Deterministic navigation

One of the initial methods aims to find every path that might connect two places and select the shortest one. Potential fields and Voronoi diagrams are utilised in two examples of algorithms.

6.1. Potential fields

The potential fields procedure, which may be employed to plan regionally in uncharted areas, is based on reactive planning approaches. The robot is viewed as a particle being pulled towards a target place by an artificial potential field using this method, which gives the obstacles features that an electrostatic potential may have. The potential fields method, which can be used to plan locally in uncharted areas, is based on reactive planning techniques. The robot is viewed as a particle being pulled towards a target place by an artificial potential field in this manner, which gives the obstacles features that an electrostatic potential may have.Any physical field that abides by Laplace's equation is a potential field. Electrical, magnetic, and gravitational fields are a few typical examples of potential fields. A robot's movement within a specific area is controlled by a potential field algorithm using an artificial potential field. We assume an area to be partitioned for our convenience into a grid of cells with barriers and a goal node.Using the potential field functions, the method assigns a fake potential field to every place on the planet. From the utmost potential to the lowest potential, the robot simulates. In this case, the initial node will have the most potential while the goal node has the smallest potential. Since the UAV progresses from lowest to highest potential.

6.2. Voronoi diagram

The process of creating Voronoi diagrams looks for the safest route between two points in space while maximising the distance between the robot and the obstacles [12]. The figure is therefore described as the location of configurations that are equally spaced from barriers.According to the cost function of the maximum distance between obstacles, the algorithm splits the space into sections formed by vertices and segments, The path from the starting point to the goal is then sought after. Obstacles are represented more realistically by polygons because they aren't actually points in real life.The nodes of the algorithm are the sites where the lines that run through the pixels of the image intersect, and the pixels are the results of the morphological operations on the image.A Voronoi diagram-generated trajectory has the drawback of being suboptimal in terms of distance travelled and may also contain a lot of turns [13]. Additionally, this approach is ineffective for dimensions beyond two (Fig. 3).

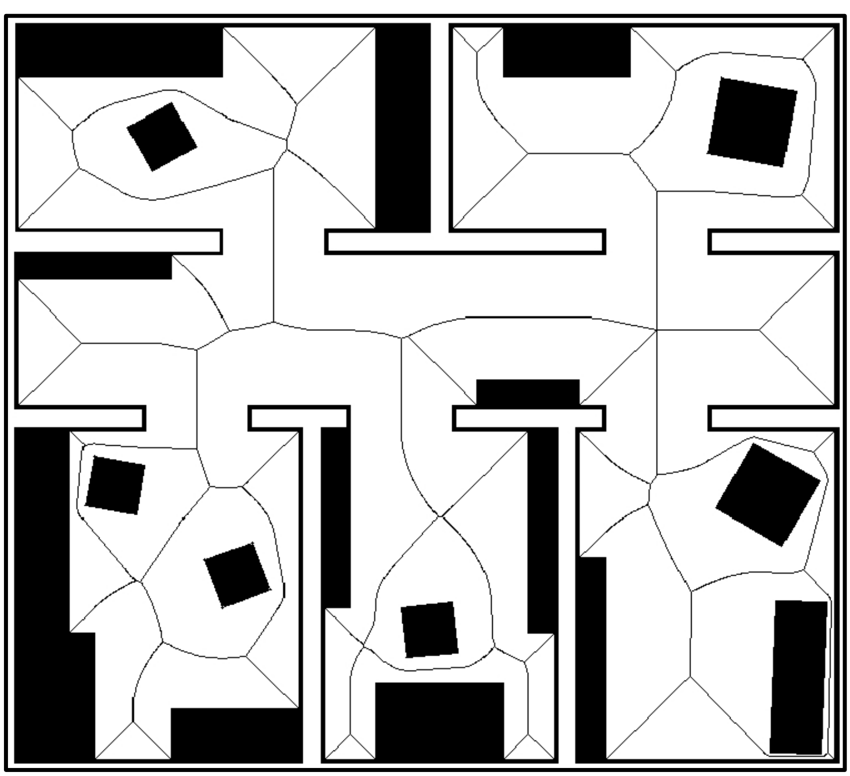

Fig. 3: Voronoi diagram in a navigation map [14].

7. Topological Navigation

The navigational procedures that use a topological representation of the environment are referred to as topological navigation. A topological representation is characterised by identifying environment reference elements in accordance with their various relationships. Reference components are referred to as nodes, and the connections between them are known as arches. To improve the understanding between humans and robots, topological navigation aims to create navigational behaviours that are more akin to those of humans. highlighting the key effects of topological navigation. An perfect relationship between the environment and the representation is necessary for topological maps based on geometry. In contrast to topological representations based on movements, where it is not necessary to have a metrical connection with the elements of the environment, every topological node is metrically related with a location or place in the environment.

8. Semantic Navigation

Robotics is currently moving away from representation models that are most closely related to the hardware of the robot, such as geometric models, and towards representation models that are more analogous to how people reason, with which the robot will interact. It aims to make robots' representations of the environment and their planning processes more similar to those of humans. Utilising behavior-based mechanisms based on human psychology is currently popular. Robots are given cognitive architectures so they can represent their surroundings using semantic concepts, which gives them more autonomy and makes navigation more reliable and effective.

9. Conclusion

This article's goal was to outline various strategies for indoor-based global navigation systems for mobility robots. Current innovations and numerous studies are aimed at addressing certain navigational demands. Our goal is to combine all of these improvements in order to categorise them and provide a universal framework for navigation.This article presents a variety of trends and methodologies, all of which are motivated by biological models and focused on human capacities and abstraction models. To accomplish local navigation and exact path-planning, the geometric representation that is more analogous to the world of sensors and actuators is the most effective. Large navigation tasks are made possible by topological representation of the environment, which is built on graphs and employs models comparable to those used by humans.The semantic representation , which is the most similar to cognitive human models, adds ideas like benefits or meanings of the elements in the environment and creates intricate relationships between them. These representations are all based on the knowledge that is currently known about the environment. Because of this, perception is crucial for comprehending and navigating the world.

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