Navigation Techniques and Algorithms for Mobile Robots and Automated Guided Vehicles

Andrzej Wajda
Data Science, University of Wrocław, Wrocław, Poland.
andajda@uwr.edu.pl

Correspondence should be addressed to Andrzej Wajda: andajda@uwr.edu.pl

Abstract – Mobile robots are self-contained devices that can navigate and move around their surroundings. They observe their environment and create maps using different sensors such as lidar, Global Positioning System (GPS), and cameras. Automated Guided Vehicles (AGVs) are vehicles that can move independently utilizing different approaches such as underground cables, laser scanners, or GPS systems. This research investigates several navigation methodologies and algorithms used in AGVs and mobile robots. It focusses on the advantages of integrating lidar technology with other sensors as well as how it is used in local navigation techniques. We look at two motion planning techniques for obstacle avoidance: the Artificial Potential Field (APF) approach and the Vector Field Histogram (VFH) algorithm. Two effective techniques for finding the best routes are discussed: the A* algorithm and Dijkstra's algorithm. The various AGV types and their navigation systems (such as wired, guide, laser, vision-based, and gyro-based) are also examined in the study. Neural networks and fuzzy logic are investigated as AGV control techniques, with line following and obstacle avoidance as examples of their use. The study emphasizes how crucial precise and dependable navigation systems are to the effective and secure operation of mobile robots and AGVs.

Keywords – Artificial Potential Field (APF), Automated Guided Vehicles (AGVs), Vector Field Histogram (VFH), Light Detection and Ranging (LIDAR).

I.   INTRODUCTION

Navigation may be defined as the methodical procedure of ascertaining an acceptable and secure route between the initial and final points, which the robot then follows. Subsequent maneuvering on a mobile robot may be described as the capacity to travel inside a certain environment or the scientific process of directing a mobile robot's movement in that environment. The challenges associated with this process can be broken down into three navigational questions: "What is my current place?" "What is my destination?". and "How do I get to my destination?". The first and second problems can be solved by equipping robots with appropriate sensors, while the third question can be solved by an efficient navigation system with a flying system effectiveness of the application. Consequently, it is important to design the robot and its operating environment in such a way that they complement each other in specific ways. Vision-based guidance has been greatly improved by the hybridization of several autonomous vehicles, such as aerial unmanned aerial vehicles (UAVs) [1], autonomous underwater vehicles (AUV) for maritime [2], and autonomous ground vehicles (AGV) [3] for land.

Irrespective of the specific vehicle or robot being constructed, the utilization for navigation purposes of a vision sensor can be broadly categorized into two types: systems that rely on pre-existing knowledge of the environment in which they will operate (requiring maps or similar data), and systems that perceive and respond to the environmental conditions they encounter during navigation. Systems that need a map may be categorized into two types: topological map-based systems and folder-based systems. A map-using navigation system, as the name implies, should include a comprehensive map of the surroundings prior to commencing navigation. The metric map-building methods are constructed and used across the map itself during the subsequent phase of navigation. Additionally, another system in this category is one that is capable of autonomously determining its own location in the environment while concurrently creating a map for the purpose of navigation and exploration. Alternative forms of cartographic navigation systems that may be encountered include systems that are local folder-based or systems that are visual sonar-based. Both of these technologies gather habitat information while traveling and create a local repository to facilitate accurate navigation.

The local map comprises the mapping of both the barrier and the surrounding environment, which is typically considered by camera`s sector of view. The final system is a topological map-based system. It constructs a topology map composed of

nodes connected by lines. The nodes represent specific positions in the environment, while the lines represent the travel time or distance between the nodes. The next generation of mobility is a mapless navigation system. These systems are mainly based on techniques using visual cues. These signals come from detection processing properties, optical flux, image segmentation, between image frames.

The purpose of this article is to explore and test a range of navigation strategies and algorithms for mobile robots and active guided vehicles (AGVs). Navigation is an important aspect of robotic and AGV systems because it determines the capabilities so that this robot can operate efficiently and safely inside design. With design, lidar-based design, and gold-based visibility design, researchers can examine the strengths and limitations of each method to determine the best routing for an application. The research also focuses on routing techniques, such as Vector Field Histogram (VFH) algorithm [4], Dijkstra algorithm [5], Artificial Potential Field (APF) technique [6], and A* algorithm [7]. These algorithms integrate path planning and proven usefulness in obstacle avoidance within robotic and AGV systems.

This paper contributes to the body of research by helping researchers to analyze and evaluate various policies and study their performance, efficiency and limitations. This information can help in designing new policies or current developments of mobility knowledge of mobile robots and AGVs. Studies under development have looked at the application of simple neural models to navigation as well. Neural fuzzy logic networks are effective techniques for dealing with data uncertainties and inaccuracies, which are common in sensor measurements and navigation decisions. Researchers combine these techniques with navigation systems and mobile robots. In general, this research seeks to enhance robotic and AGV systems through the use of navigation techniques and control systems. The results can be used to improve the communication skills of these robots, enabling them to perform efficiently and reliably in a variety of tasks and applications.

The rest of the article has been organized as follows: Section II describes the local navigation methods: light detection and ranging, and the vector field histogram. Section III focusses on global navigation methods: artificial potential field, Dijkstra, and the A* algorithm. Section IV review navigation methods and applications for autonomous guided vehicles. Section V presents a conclusion and future research directions.

II.   LOCAL NAVIGATION METHODS

Light Detection and Ranging

Many sensors employ the method of local navigation to effectively control the location and orientation of robot. The technique of LiDAR (light detection and ranging) employs sensors, which are vital for the process of automation. LiDAR, when compared to the GPS system, operates independently permitting it to effectively navigate the environment. The technique may operate independently; nonetheless, when incorporate with other sensors (GPS, Inertia Navigation System, and cameras), it generates more advanced results. When this technology is employed in cameras, it operates as a powerful equipment for effectively establishing an accurate position. LiDAR may be employed to produced cartographic representations for closer environments and determine precise locations, and essential features within the environment. SLAM (Simultaneous Localization and Mapping) is a vital technique use to achieve this fundamental cartographic activity. This technique permits mobile robots to effectively rectify/adjust its position and orientation from remote environments. Using motor encoders and LiDAR has the capacity to effectively boost precision.

To effectively validate the aspect of linear regression precision described in [8] Kavitha et al. employed a simulation approach of various cases where the target moved closer to the sensors with different velocities and distance. A three-dimensional model of a DJI F450 was scanned for 0.5 seconds, resulting in the capture of point clouds like those shown in **Fig 1**.
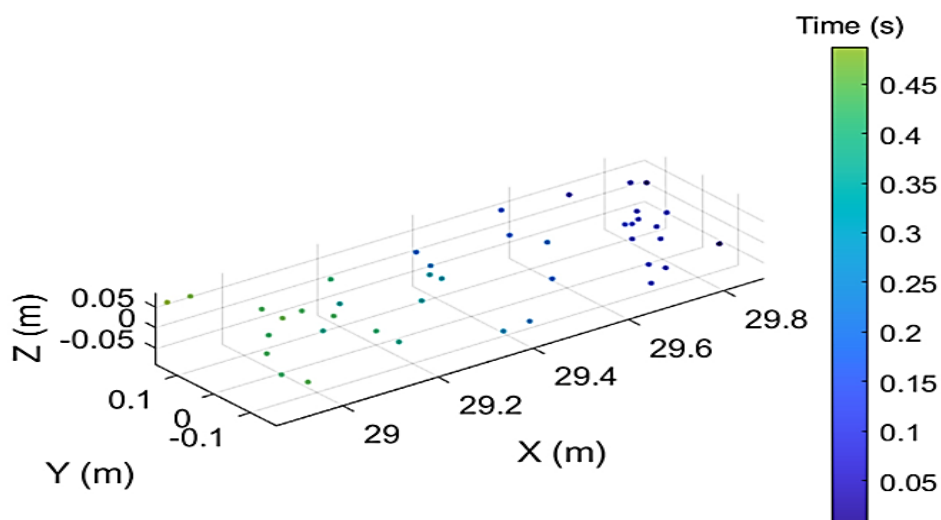

Fig 1. Dynamic Point Cloud Sampled.

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Table 1 displays the regression findings, including the 95% confidence interval for several scenarios. The discrepancies in both the velocity and the y-coordinate at the starting point are approximately at the centimeter level. The outcome is satisfactory given the instrument's accuracy and the sparse distribution of data points. The accuracy of the measurements was somewhat reduced over a distance of 30 meters due to a smaller number of data points collected. The sensor has a tendency to locate the target somewhat closer to its location. This is because the majority of the recorded data points, as a result of the sensor's visual range, align with the frontal area of the DJI F450.

Table 1. Findings From Linear Regression Analysis

Distance (m)	Real Velocity (m/s)	a_t (m)	b_t $\left(\frac{m}{s}\right)$
10	-2	9.94 ± 0.03	-2.01± 0.02
10	-5	9.94 ± 0.03	-5.00 ± 0.05
10	-10	9.96 ± 0.03	-9.96 ± 0.05
30	-2	29.95 ± 0.03	-2.06 ± 0.13
30	-5	29.97 ± 0.03	-5.03 ±0.14
30	-10	29.95 ± 0.03	-10.02 ± 0.12

Vector Field Histogram

The VFH is a motion planning approach in robotics that was introduced by [9]. The VFH relies on a robot`s model of statistic around the surroundings using a histogram grid. It prioritizes handling uncertainty caused by inaccuracies in modeling and sensors. The VFH algorithm distinguishes itself from other algorithms of barrier avoidance by taking both the robot`s shape and dynamics. It generates signals that are specifically designed to match the distinct characteristics of the platform. The VFH, while primarily a local route planner and not intended for global path optimization, has been shown to generate pathways that are very close to optimum. The first VFH technique was developed using prior research on the Virtual Force Field, which is a local path-planning system. The VFH algorithm underwent an upgrade in 1998 by Iwan Ulrich and Johann Borenstein, resulting in its renaming as VFH+ (informally referred to as "Enhanced VFH") [10].

The technique underwent further upgrade in 2000 by Ulrich and Borenstein, resulting in its renaming as VFH* [11]. Currently, VFH is widely used as a local planner in mobile robots and is considered one of the most popular options. It competes with the dynamic window technique, which was created later. Several robotic development tools and simulation environments, like the Player Project, include integrated support for the VFH algorithm. The development of the Vector Field Histogram focused on achieving computing efficiency, robustness, and insensitivity to misreadings. The VFH algorithm has shown its efficacy in terms of speed and reliability, particularly when navigating through obstacle courses with high population density. The VFH technique utilizes statistical depiction of obstacles, specifically employing histogram grids (sometimes referred to as occupancy grids). This style is ideal for handling imprecise sensor information and allows for the combination of several sensor values. The VFH algorithm has three primary constituents, as seen in **Table 2**.

Table 2. Components of The VFH Algorithm

Component	Description	Literature
Cartesian histogram grid	A grid is formed by utilizing the robot's range sensors, such as a laser or a sonar rangefinder, to precisely calculate distances inside a two-dimensional Cartesian coordinate system. The grid is constantly refreshed in real-time.	Clain, Lopes, and Pereira [12]
Polar histogram	A unidimensional polar histogram is generated by decreasing the Cartesian histogram that is centered on the present position of the robot.	Borenstein and Koren [13]
Candidate valley	Successive sectors that have a polar barrier density below a certain level, referred to as candidate valleys, are chosen based on their closeness to the goal direction.	Hwang and Ahuja [14]

After identifying the central point of the chosen candidate direction, the robot adjusts its orientation to match with it. The velocity of the robot is diminished when it encounters impediments directly in its path. The concept of VFH is derived from the VFF (Virtual Force Field) [15] technique. The field, as its name suggests, applies a repulsive force on the vehicle when impediments are identified at a specific distance, causing the vehicle to move away from the obstacles. Additionally, an attractive force is used to lure the vehicle towards the objective point. The VFH system use a radar display that takes the form of a grid, where the sensor increase the confidence value at the corresponding positions on the grid. A higher confidence value implies that the sensor's range has accurately identified the specific object. The grid is refreshed in real time, ensuring that it is continually and instantly updated. This makes it particularly ideal for sparse moving objects.

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<div align="center">III.   GLOBAL NAVIGATION METHODS</div>

Artificial Potential Field

The Artificial Potential Field (APF) system operates by using the principles of attracted and repulsive forces, as seen in **Fig 2**. As seen in the diagram, the AMR experiences force fields originating from the objective point located at x_g, y_g and the obstacle situated at x_o^k, y_o^k. The attractive force, denoted as $\overline{F_{rep}}$, is produced by the objective, whereas the repulsive force, denoted as $\overline{F_{rep}}$, is produced by the barrier. The route planning issue is simplified by considering the Autonomous Mobile Robot (AMR) as a point mass. The expression of $\overline{F_{rep}}$ is represented using the Gaussian function.
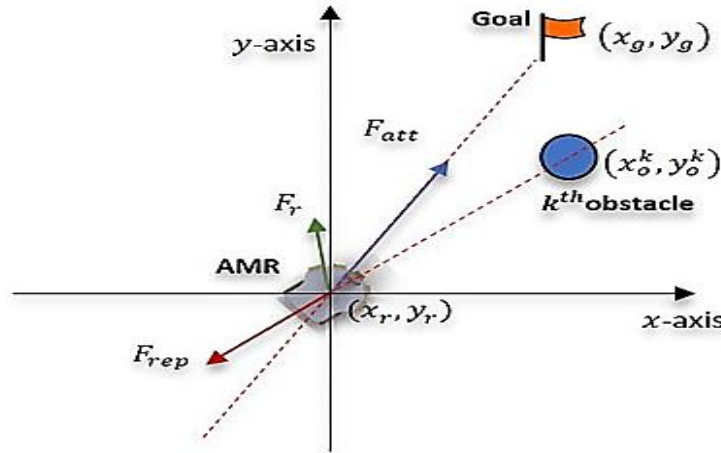

Fig 2. An Overview of Route Planning Using APF When There is an Impediment Present.

The Potential function may be expressed for both repulsive and attracting forces, as seen in Equations 1–5.

$$U(q) = U_{att}\,(q) + U_{rep}(q) \tag{1}$$

Frequently used attractive potential is:

$$U_{att}(q) = \frac{1}{2}\varsigma p^2(q.q_{goal}) \tag{2}$$

where ζ represents the gain, and (q, q_{goal}) represents the distance among the goal and the robot. The force of attraction may be defined as the opposite slope of the attractive potential. Additionally, when the force of attraction reaches the target, it will be deemed to be zero.

$$F_{att(q)=-}\nabla U_{att}(q) = \varsigma\big(q_{goal} - q\big) \tag{3}$$

The repulsive potential function provided below may be used.

$$U_{rep}(q) = \left\{\frac{1}{2}n\left(\frac{1}{\rho(q.q_{obs})} - \frac{1}{\rho_e}\right)^2 \tag{4}\right.$$

If $\rho(q.q_{obs}) < \rho_o$
The repellent potential function's negative gradient:

$$F_{req}(q) = -\nabla U_{req}(q) = \left\{\varsigma\left(\frac{1}{\rho\left((q.q_{obs}) - \frac{1}{\rho o}\right)}\frac{1}{p(q)^2}\frac{q - q_{obs}}{p(q)}\right. \tag{5}\right.$$

The potential field strategy involves creating an appealing field to guide towards the objective. The potential field is typically specified over the whole unoccupied area, and at each time interval, the potential sector is computed at the robot's location, determining the force exerted by the sector. The robot should then move in accordance with the forces described before. The primary issue with APF is the potential for the robot to get confined in a local or world minima challenge. This means that the robot may become stuck at a location where the opposing fields or forces neutralize each other, hindering the robot from moving backward or even forward.

$$\bar{F}_{att} = a_{g1-e}\left(-b_g.d_g^2\right).e_g \tag{6}$$

where d_g represents the maximum $\overline{F_{rep}}$ value at any case, b_g represents the constant that shows the distribution width, and d_g presents the Euclidean range between the goal and AMR, $d_g = \sqrt{\Lambda x_g{}^2 + \Delta y_g{}^2}$, where Λx_g represents $x_g - x_r$ and Λy_g represents $y_g - x_r$. The e_g parameter represents the unit vector toward specific goals point that can be defined as:

$$eg = \frac{1}{d_g}\left(\Delta x_g + \Delta y_g\right) \tag{7}$$

Dijkstra

Numerous methods are available to address the shortest route issue. One particular example of the greedy algorithm is Dijkstra's algorithm. The approach incorporates an algorithm of a graph search that solves the shortest route issue with a single source on a network without negative edge costs, and generates the minimum spanning tree. The method is used in routing. A heuristic is a technique specifically developed to expedite problem-solving. This is accomplished by sacrificing correctness, precision, completeness, or optimality in favor of velocity. The A* algorithm is a graph traversal method that determines the shortest route from a specified starting node to a specified destination node. The algorithm utilizes a "heuristic estimate" $h(x)$ to provide an approximation of the optimal path passing through the given node. The algorithm traverses the nodes in accordance with their heuristic estimate, as shown by Amine and Mestari [16]. The authors conducted a comparison between Dijkstra's algorithm and A* method for solving the shortest route issue, as shown in **Table 3**. The process of mathematical modeling consists of four stages: interpretation of the mathematical answer, issue identification, determination of a mathematical solution based on the model and construction of a mathematical model in terms of real-world problem perspectives.

Table 3. Overall Duration from The Start Location to The End Point Using A* And Dijkstra

Test Number	**Running Time Dijkstra (nanoseconds)**	**Running Time A* (nanoseconds)**	**Total Distance (in km)**
1	997.200	996.800	4.504
2	998.200	996.900	4.504
3	997.800	997.400	4.504

A Algorithm*

This algorithm may be employed as a research instrument in the identification of paths. The algorithm is well-establish as a reliable approach for mitigating issues related with path finding. In addition, the algorithm is typically employed in numerous strategy-oriented gaming applications. Its stability and speed have significantly advanced in the last decade, and more enhancements are anticipated in the near future. However, the A* algorithm is not infallible, since it often requires an additional algorithm or modification to its fundamental functions in order to successfully handle complex jobs. The A* algorithm faces several challenges, such as competing paths among multiple agents, as seen in Multi-Agent Pathfinding problems. The researcher also considered the layouts of these test samples. In one of the articles, the Algorithm was tested on maps that had identical characteristics but a different grid design. The A* algorithm has the ability to find a route more quickly than an uninformed search, but it does not provide a guarantee that the path chosen will be the shortest. When using strategy maps and mazes, the A* method is successful in finding the shortest route around 85% of the time.

A* is often selected because of its precision, efficiency, and temporal complexity; nevertheless, it does have its limitations. The data it consumes necessitates a somewhat large memory storage capacity. If computing speed or complexity are more important factors than other issues, then A* is frequently considered the top option. One potential approach to examine is to reassess each issue and see if they really get advantages from using the A* algorithm. Every project is unique and priorities vary, making it beneficial to explore algorithms like Dijkstra or Deepening Iterative Search. Dijkstra's algorithm is particularly effective when the time spent on generating a heuristic may be more efficiently used for exploration. Other algorithms, such as Conflict-Based Search, are also competitors for Multi-Agent Pathfinding, aiming to compete A* algorithm. The performance of this Algorithm was superior than previous A-STAR-based Algorithms when evaluated on a randomly created dataset. These considerations demonstrate that there is still significant room for development in the A* Algorithm, particularly in circumstances like these. Although some may claim that these cases are simply a niche, Multi-Agent issues will become more common in the future.

The program iteratively explores uncharted nodes in the network. The method terminates after the target site is reached, after searching all the places in the graph. If the objective is not reached, it assigns all the adjacent nodes to explore and find the shortest route. The A-star technique is widely used for pathfinding in games.

IV.   NAVIGATION METHODS AND APPLICATIONS FOR AUTONOMOUS GUIDED VEHICLES

Overview of AGVs and The Navigation Guidance System

Automated guided vehicles (AGVs) provide advantages similar to conveyors, but with more adaptability and less hindrance on the industrial premises. Nevertheless, they are unable of processing the same amount of material as a conveyor, lack the natural ability to store excess items, and are more costly. An AGV, or Automated Guided Vehicle, is a self-operating vehicle that navigates autonomously inside the industrial premises. This may be accomplished by the use of an underground wire that the vehicle can detect and then track. It is possible to provide many routes and intersections that may be chosen by the central control system to enable the AGV to transport items by different paths to numerous operations. The AGVs often operate in shared workspaces with other users, like the workforce and forklift trucks. Consequently, they are equipped with suitable safety systems. AGVs, while they have some advantages, are comparatively sluggish and have restrictions regarding the dimensions and mass of the products they can manage. Due to the need on subterranean wiring, modifying or expanding an AGV system might incur significant costs. There are also self-guided cars that use an internal GPS system or laser scanners and wall-mounted targets to ascertain their position. Self-guided vehicle systems provide more flexibility in the long run since they are less restricted and easier to modify.
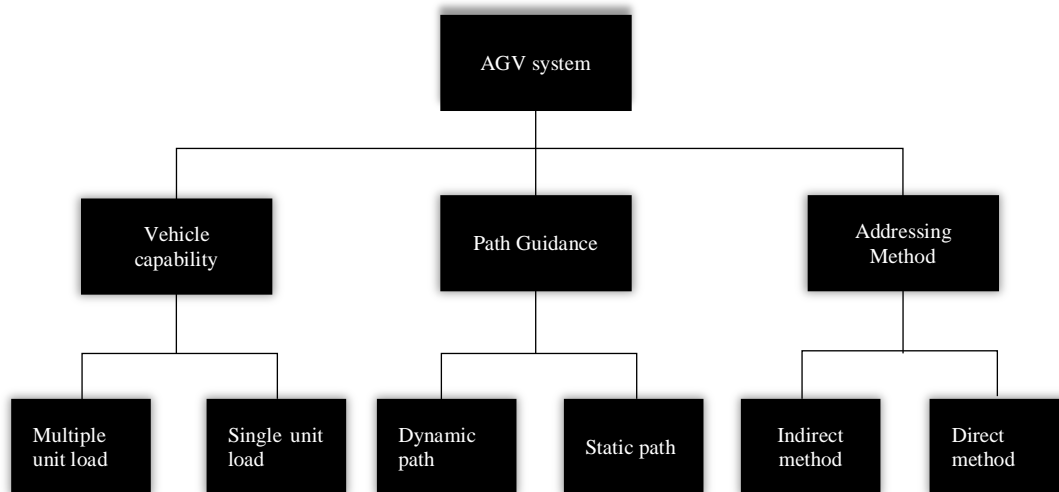
Fig 3. Sub-Division of Various AGV System.

The AGV system may be categorized into many groups, as seen in **Fig 3**. Two distinct classifications of AGVs are possible according to the number of cargo units that can be carried concurrently: Multiple or Single Unit Loads. A load is defined as a singular entity that transports a vehicle from its place of origin to its destination. In the single unit load system, a vacant and inactive vehicle is selected to carry out the duty of transporting the cargo to the designated location. The vehicle returns to its drop-off location after transporting the cargo from its origin to the pick-up location. The cargo drop-off assignment work does not result in any disruptions to the vehicle caused by other duties. The multiple unit load system entails a temporary cessation of operation for fully laden vehicles to accommodate the collection of additional cargoes. Reallocating a vehicle to a new job has an impact on both the existing load for the present work and any extra weight that the vehicle will be carrying. Hence, the controller should include scheduling and planning function parameters to ascertain the allocation of vehicles for load transportation.

The guidance for AGV's route may be categorized as either dynamic or static path determinations. A static path vehicle follows a predetermined route from its starting point to its destination. The direct steering system of the vehicle utilizes many technologies such as dead reckoning, implanted wire, radio-frequency identification (RFID) chips, and magnetic tapes. The concept of a static route may be further classified into two distinct categories: bidirectional and unidirectional. In a unidirectional system, vehicles are restricted to go in a single direction. In contrast, a bidirectional system allows vehicles to move in either direction. This is made possible by employing bidirectional vehicles or turn-around sites that can drive both backward or forward. In a dynamic path system, the vehicle operates independently to select its course by recognizing and evading obstacles. The vehicle in this system is aware of its destination using a coordinate system. A car use an internal navigation system to reach its intended location.

AGVs may be categorized as either direct or indirect based on their addressing modalities. The direct addressing method might be likened to a city taxi service, where a vehicle serves as a means to transport a passenger to their desired location. In AGV, the planning function utilizes the current system state to determine the optimal path for the vehicle, starting from its initial point and ending at the desired destination position. In a system that uses indirect addressing, the vehicle's path may not always contain every station it comes across. The stations are partitioned in such a way that the AGV must be reached by every stations subset. The AGV devises the optimal path and utilizes a subset of stations to reach its intended destination.

The Navigation guidance system is a system that provides concise and precise instructions for navigating a certain route or path. The system may be categorized as Absolute, Relative, and Direct systems based on the kind of system being used, as seen in **Table 4**.

Table 4. Types of The Navigation Guidance System

Type	Description	Literature
Wired Type	Wired-type navigation employs a groove or filament that is incised and positioned under the ground. A sensor is positioned in the lower part of the AGV to identify its location based on the radio signal it receives. This information is then used by the steering circuit to assist the AGV in following its designated path.	Nguyen, Jenssen, and Roverso [17]
Guide Type	The Guide-type sensor vehicle use a camera to track and follow a designated course marked by either a tape or a painted line. The data is sent by radio communication. The benefit of a guide route is its versatility in being able to be relocated and removed from any location.	Manikandan, Kaliyaperumal, Hakak, and Gadekallu [18]
Laser Type	Laser Navigation is often regarded as the most optimal and proficient method for avoiding obstacles and following a desired path. The mobility of this object does not rely on the use of wires, rails, or tracks. A beam is emitted and detected by a sensor. The duration of the beam's round trip is used to calculate the distance and angle, which in turn assist the vehicle in its movement. The present position of the AGV is compared to the pre-existing map stored in the AGV's memory.	Stahn, Heiserich, and Stopp [19]
Gyro based	The navigation of the vehicle may be accomplished via the use of a computer control system that directs and allocates tasks. Transponders are used for this specific objective, being concealed under the floor aids the vehicle in verifying its precise location and orientation. Navigation is accomplished via a gyroscopic sensor. The integration of gyroscopic readings and laser sensor provides an alternative approach to determine distances. The approach is particularly efficient for calculating the shortest route inside a given path.	Bourke and Lyons [20]
Vision Based	Visual-based AGVs use cameras to capture environmental characteristics and utilize these elements to make informed decisions for vehicle navigation. Conversely, Geo guidance comprehends its surroundings via the utilization of location. The system utilizes a static reference point to accurately identify and locate any item inside the warehouse. With this information, the truck is able to autonomously navigate. The effective administration of vehicle duties is crucial in an automated guided vehicle system. The controller governs all the tasks.	Zheng and Lu [21]

Navigation System Methods

Fuzzy logic plays a crucial role in controlling mobile robots and autonomous guided vehicles. They are most effectively used for imprecise and unreliable data and knowledge based on heuristics. They may be integrated with a system of AGV to regulate the movement and direction of the motor. Fuzzy logic operates on a system that is built on rules, allowing for the creation of various rules to control an AGV. The vehicle and obstacle location are collected via sensors used on the AGV during the process of fuzzification. A route following rule base is developed and combined with an inference system of fuzzy to determine the optimal way for the locomotion of the AGV, as seen in **Fig 4**.

Likewise, NN may be used for AGV systems in a similar fashion. The neural network system is based on the functioning of the biological nervous system, similar to how the brain processes information. It consists of artificial neurons that are interconnected and collaborate to provide a specified output. Acquiring knowledge about the biological system requires adapting to the complex network of synaptic connections between neurons, which alter themselves based on the available data. Neural networks possess the inclination to acquire knowledge from their surroundings and are designed to enhance their efficiency via experiential learning. Additionally, they are highly adaptable to perturbations in their environments. The integration of several navigation approaches with a fuzzy logic controller and neural network enables the attainment of superior and exceptionally efficient outcomes in relation to both position and orientation.

Various line following techniques have been proposed by researchers. Hamam and Georganas [22] introduced a method for path flow using the Sugeno Inference Method. They adapted a magnetic guide by including an 8-bit input line sensor to assign weights for the purpose of determining the required output. The weighted data is used as input for a separate controller for ambiguous logic to determine the precise velocity for the queue following robot. The utilization of many sensor varieties facilitates the guidance of the robot to circumvent barriers and adhere to a certain trajectory. The route following strategy utilizes techniques of wire-guided, in which an electrically conductive wire is embedded in the floor. Using an ultrasonic

sensor, the car can autonomously navigate back onto the wire if it detects an obstacle. The use of an ultrasonic sensor is regarded as a rather unsophisticated approach to prevent and identify obstacles. In [23] have suggested a fuzzy logic-based obstacle avoidance approach that utilizes individual input sensors.
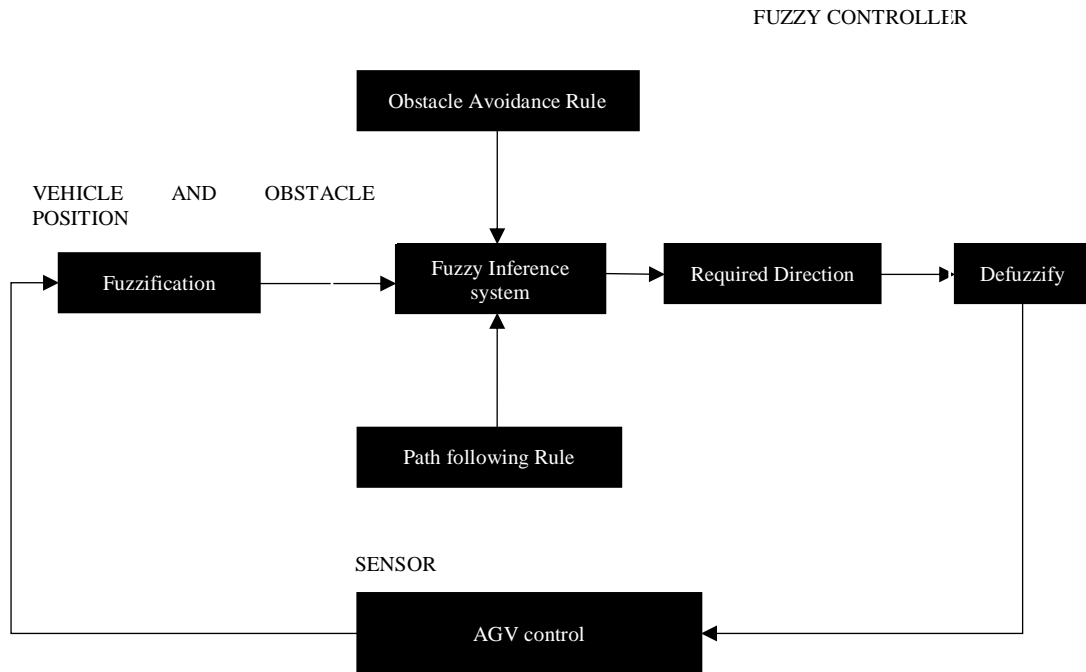
FUZZY CONTROLLER

VEHICLE AND OBSTACLE POSITION

Fig 4. The Fuzzy Controller is Shown Using a Functional Block Diagram.

Antonelli, Chiaverini, and Fusco [24] used Fuzzy Logic to govern and accurately follow the path of an independent unicycle robot. Saffiotti [25] have studied the use of controller for ambiguous logic in managing a mobile robotics for education to avoid barriers. In the study conducted by Linda and Manic [26], an autonomous robot was designed to handle imprecise and uncertain data. The main objective of the robot was to recognize and respond to real-time maneuvering scenarios. The study presents a methodology based on fuzzy rules to govern the motion and behavior of an independent robot. The control and guidance of the robot are achieved by integrating local actions and global strategies inside the fuzzy controller. Another robot that uses a fuzzy control system and an obstacle avoidance algorithm is described in the study by Yi, Zhang, Ning, and Huang [27]. This robot is capable of moving along a predetermined route while controlling its angular speed, linear speed, distance, and angle. The performance of the fuzzy logic controller exhibited good behavior in effectively circumventing barriers.

The study conducted by Fazlollahtabar and Saidi-Mehrabad [28] presents an investigation into a unique category of AGV routing issue. The primary challenge for free-ranging AGVs is to choose the most efficient route to perform various pick-up and delivery jobs. An Artificial Neural Network (ANN) method was developed using Kohonen's self-organizing maps as a basis. A [29] examined the challenges of mobile robot navigation and the use of neural networks inspired by biology to avoid obstacles. Scaramuzza et al. [30] have highlighted the goal of developing a robot capable of navigating through unfamiliar environments while carrying out essential delivery jobs. The robot used both infrared and sonar sensors, however the fusion of these two sensors resulted in inconsistent and incorrect data. In order to do this task, the robot needs possess previous knowledge about the surroundings or a map of the structure. Sensor fusion is not adequately addressed by simple methods, which is why a Neural Network System was offered as a solution. NN has shown its ability to provide accurate and dependable data.

V.   CONCLUSION AND FUTURE RESEARCH

Mobile robot navigation entails calculating a safe and appropriate path between beginning and end destinations. There are two kinds of map-based navigation systems: topological map-based and folder-based map-based systems. Lidar is often utilized in local navigation techniques to control the location and orientation of the robot. The Vector Field Histogram (VFH) method is frequently employed as a local planner in mobile robotics, taking into account the robot's kinematics and structure. The Artificial Potential Field (APF) method guides the robot toward the goal while avoiding obstacles by using attracting and repulsive forces. Dijkstra's algorithm and A* algorithm are both extensively used for path-finding, with Dijkstra's approach being more successful at identifying a non-obstructive route and A* algorithm giving accuracy and efficiency. AGVs (Automated Guided Vehicles) have benefits in industrial settings, however their speed and product dimensions are limited. AGVs are classified according to their load systems and addressing modes. AGV navigation is guided by navigation guidance systems such as wired, guide, laser, and vision-based. Fuzzy logic and neural networks are utilized to regulate

AGVs, particularly when dealing with unreliable and inaccurate data. To control AGVs, several line following approaches, such as the Sugeno Inference Method, have been deployed. The use of artificial neural networks for effective AGV navigation in new areas has also been investigated by researchers.

There are various areas that may be further studied and enhanced in the future.

Sensor integration
Combining diverse sensors, such as lidar, cameras, and inertial navigation systems, may improve the accuracy and reliability of navigation systems. More research may be done to enhance the overall performance of mobile robots by enhancing sensor fusion methods.

Sophisticated path planning approaches
Even though the A* and Dijkstra algorithms are significantly employed, there is still many sectors of path planning that can be developed. Future research can concentrate on developing sophisticated algorithms that are able to handle multiple agents, complex configurations, and dynamic challenges.

Real-time avoidance of obstacles
 Boosting the capacity of object avoidance by robotic systems is fundamental for enhancing navigation and security. In that case, future research should focus on developing real-time approaches for identifying and eliminating obstacles within unpredictable and dynamic environments.

This research contribution reviews various aspects of robotic navigation and recommends directions for future research. It discusses a number of navigation systems such as map-based bag-based systems, and highlights the use of lidar technology for map localization The paper also covers route planning and obstacle avoidance methods such as vector field histogram (VFH), Dijkstra's algorithm, artificial potential field (APF), A* algorithms etc. The paper investigates navigation techniques used in active guided vehicles (AGVs) and navigation guidance systems; as well as the application of neural fuzzy logic networks in AGV control. In general, there is much potential for future development in mobile robotic communication. Researchers can solve the challenges and find new ways to improve the capabilities of mobile robots in many areas.

Data Availability
No data was used to support this study.

Conflicts of Interests
The author(s) declare(s) that they have no conflicts of interest.

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Competing Interests
There are no competing interests.

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