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# Intelligent Obstacle Avoiding AGV Using Vector Field Histogram and Supervisory Control

S. S. Bolbhat<sup>1</sup>, A. S. Bhosale<sup>1</sup>, G. Sakthivel<sup>1,2</sup>, D. Saravanakumar<sup>1</sup>, R. Sivakumar<sup>3</sup> and Lakshmipathi J<sup>3</sup>.

<sup>1</sup>Centre for Automation, School of Mechanical Engineering, Vellore Institute of Technology, Chennai (600127), Tamil Nadu

<sup>3</sup>School of Mechanical Engineering, Vellore Institute of Technology, Chennai (600127), Tamil Nadu

<sup>2</sup>Corresponding Author: Sakthivel.g@vit.ac.in

**Abstract.** Automated Guided Vehicles are used to help the process of carrying materials from one place to another. AGVs are widely used in the materials handling process in different industries hence, the reasoning behind their extremely wide usage in industries such as Automotive, manufacturing, Medical, etc. This research deals with the obstacle avoidance of Automated Guided Vehicles (AGV). This paper propose an algorithm that helps to build obstacle-free trajectories for AGV that leave the original track and again get back to the original track by avoiding the obstacle. The new path also have to act according to the dynamic & kinematic constraints of the AGV. The proposed method will be validated using simulations.

## 1. Introduction

Good material handling is an important parameter of every manufacturing industry, without material handling final product will not turn into good profit. The material handling needs to be done with safely, effectively with possibly minimum cost in the desired time, accurately without damage to the material. The cost of material handling in the industry is a portion of production cost and estimating around 15-25% of complete manufacturing cost [1]. Automated guided vehicles are a programmable mobile vehicle that is intensively used in industries to carry materials and parts in manufacturing and assembly units. The uses of AGV has increased since its introduction, the number of areas of application and variation type has increased significantly [1]. Recently AGV extended its popularity to other applications.

In the past years, many research done work on different AGV technology. The total number of AGVs manufactured in the world are currently used in a different industry for material handling. In this paper, we provide information about the design and development of a low-cost AGV that can be used in industries for material handling. Section 3 of this paper presents the design of chassis of AGV and Selection of material for the chassis. Section 4 gives an idea of the selection of the sensor, motor torque calculation, controller and their interfacing with the AVG. The kinematics of AGV given in section 5. Section 6 represents a Simulink model of the proposed AGV model by using MATLAB. Testing and Result are given in section 7.

## 2. Literature review



Bug algorithm introduced by Lumelsky and Stepanov (1987) [2]. In Bug algorithm vehicle runs along with the wall of an obstacle whenever it meets one. When the direction for the goal is available, then the vehicle leaves the obstacle and reach the goal.

Borenstein and Y. Koren [3] given different methods for avoiding obstacles these methods are the vector field histogram method (VFH), Ulrich, and Borenstein [4] these are improved methods in this the size of the robot and choosing a safe, as well as the efficient angle, is considered [5].

Artificial Potential Field Method (PFM) for an obstacle avoidance vehicle described by Khatib (1985)[6]. PFM method consists of an attractive field, computationally light and a repulsive field is simple. By calculating and summed two different fields the robot follows the direction of the calculated vector. Obstacles avoidance is achieved by the repulsive field and the goal is achieved by the attractive field. Artificial potential fields can also be used as a global path planner [7].

Model Predictive Control (MPC) used by Anderson et al. [8].to develop an optimal control-based path planning method this control method used to predict vehicle movement. The drawback of this method is this approach having a nonlinear optimal control problem, and even if the problem linearized difficult to find the optimal path in real-time. This method is eminently dependent on CPU performance.

The nearness diagram (ND) method was proposed by Minguez and Montano [9], He categories real path planning situation in five categories, all these categories have different decision making procedure. Later on, this method was improved by some researchers [10–12].

The follow-the-gap method (FGM) was developed by Sezer and Gokasan [13], in this method the angle of maximum gap towards the goal is found and then weighted average of angle and angle in the direction of goal is calculated.

Park et al.[14] He found that Advanced fuzzy potential field method(AFPFM) is a superior algorithm to conventional potential field method (PFM), in which they used fuzzy membership and TS fuzzy inference[15]. In this method Attractive field of AFM is identical to conventional PFM. Only change in Repulsive field calculation which are carried out by using TS fuzzy inference.

Conclusion, there are several methods and techniques that can be used for a mobile vehicle to avoid the obstacle. Based on the related works Vector Field Histogram and Supervisory Control method are compared for better obstacle avoidance.

### 3. Frame design

In AGV the frame is an important parameter that is designed by using parametric technology. Parametric modelling provides result in different draws, rendered views, and flexibility in designing various aspects of the AGV. Stress analysis provides the final form of the frame, which is shown in Fig.1.

The frame is created by using a 1.25 mm thick square pipe, mild steel profile. It has 6 wheels in that two wheels are power wheels and 4 castor wheels. The frame is 375 mm wide, 775 mm long and 225 mm high. The powered wheels provided at the center of the frame which results in accurate turning.



Figure 1. Frame

The Loading capacity of main surface is 80 kg Vehicle is designed such that all electronic & electrical hardware can be installed in the vehicle compartment. Because of this all Sensitive parts are protected

from external effects and hazardous environmental conditions. This is a main requirement to work in most industrial environments. We also isolated the space required for batteries.

Static analysis is done, to check the strength of the frame structure. In this, the model of the vehicle is tested with different loads, the maximum load is 80 kg for estimating the limits of the design. Our main aim is to check whether plastic deformation are developed or maximum limit of yield for material is exceeded.

The ANSYS specialized Finite Element Analysis (FEA) program is used to estimate the stress which are developed. Finite Element Analysis is used widely in the development of new products. It gives platform to provide manufacturers with low-cost re-design and optimization times [16].

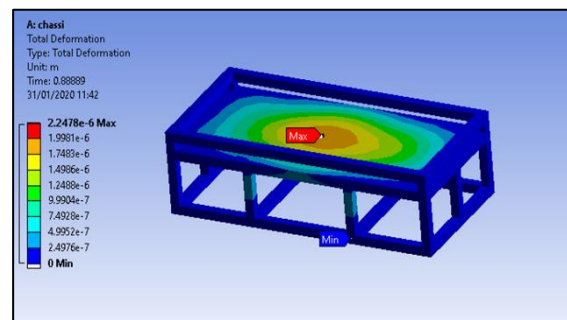


Figure 2. Frame Analysis

## 4. Component description

### 4.1. TF Mini Micro LiDAR Range Finder

The TF Mini LiDAR is a unidirectional laser range detection sensor that is based upon the technology of time of flight.

The TF Mini LiDAR having optical & electronic devices, These devices integrate with an algorithm for indoor & outdoor scenario. It has a small body & high performance in distance measurement [17]. The TF Mini LiDAR is a unidirectional laser range detection sensor which is based upon the technology time of flight.

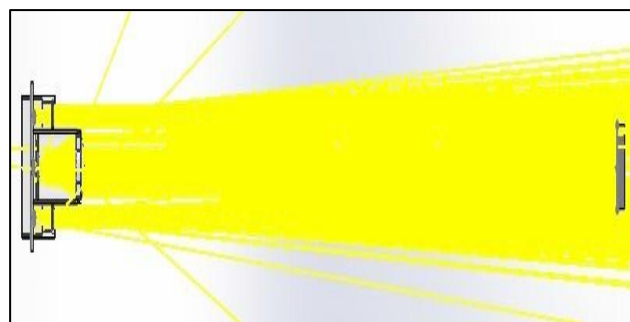


Figure 3. TF Mini Optical Stimulation Light Path

Specification: The TF mini LiDAR having an operating range from 4.5 v to 6 v. It uses a communication interface as UART (TTL). TF mini LiDAR is available in the working range of 3 m to 12 m which is good in the industry for range finding. The maximum range with the reflectivity of 10% is 5 m. Average power required 0.6 W. TF mini LiDAR have a good resolution of 5mm, Work with frequency 100 Hz, Accuracy of TF mini LiDAR is 1% and operating temperature range from 0 to 600 C.

### 4.2. Raspberry Pi

Raspberry Pi is the single-board computers which are developed by the Raspberry Pi Foundation, the main aim of Raspberry Pi is to educate people in computing and help to create access to computing knowledge. Raspberry Pi having three generations of Raspberry Pi's as Pi 1, Pi 2, and Pi 3, and there has been a Model A & a Model B of most generations. Model A is a low-cost variant with low ram RAM and minimum ports of USB and Ethernet. The Pi Zero is made even smaller and cheaper.

Specification: For AGV we are using raspberry pi which has 1 GB LPDDR 2 RAM with 900 Mhz, It consists of a communication interface as Bluetooth module 4.1 classic.

This Bluetooth module requires low energy. Raspberry pi has external storage of micro SD, It also consists of the audio jack, USB 2.0 port, Ethernet, Camera interfacing, and display interfacing port. Raspberry pi has 4X ARM Cortex A53 processor with a speed of 1.2 GHz which is good for computing.

#### 4.3. DC motor driver

For AVG we used dual bidirectional motor driver this driver based on the L298 Dual H-Bridge Motor Driver [19]. DC motor driver module allows you easy and separate control of two motors of up to current 2A in both motors in both directions [19].

Specification:

DC motor driver is L298N, the operating voltage of the driver is from +5v to +46v. For controlling action this driver required +5v to +7v power with 0.36mA current. Operating temperature range is -25 to +130 °c.

#### 4.4. Motor Selection

Motor selection is a very important parameter in AGV to move AGV with the required speed and acceleration. For the selection of motor we need to consider rolling resistance, grade resistance, acceleration force, tractive resistance. These parameters decide the performance of AGV.

**Table 1.** Value of Co-efficient of Rolling Resistance.

Contact surface	$C_{rr}$
Concrete (good/fair/poor)	0.010/0.015/0.020
Asphalt (good/fair/poor)	0.012/0.017/0.022
Macadam (good/fair/poor)	0.015/0.022/0.037
Snow (2 inch/4 inch)	0.025/0.037
Dirt (smooth/sandy)	0.025/0.037
Mud (firm/medium/soft)	0.037/0.090/0.150
Grass (firm/soft)	0.055/0.075
Sand (firm/soft/dune)	0.060/0.150/0.300

Torque required to drive AGV:

4.4.1. *Rolling Resistance:* Rolling resistance is the force required to accelerate AGV on the particular surface.

$$RR = GVW \times C_{rr}$$

RR = Rolling Resistance

GVW = Gross Vehicle Weight

$C_{rr}$  = Co-efficient of Rolling Resistance

$$GVW = m \times g$$

$$GVW = 80 \times 9.81$$

$$GVW = 784.8 \text{ N}$$

**4.4.2. Grade Resistance:** Grade Resistance is the force required to move an AGV up on the slope. This calculation are done by considering maximum angle the vehicle expected to climb in normal material handling operation.

$$GR = GVW \times \sin \theta$$

$$GR = 784.8 \times \sin(5)$$

$$GR = 68.399 \text{ N}$$

**4.4.3. Acceleration Force:** Acceleration Force is the force required to accelerate AGV from rest to maximum speed in the desired time.

$$Fa = m \times a$$

$$Fa = (GVW/g) \times a$$

$$Fa = (784.8/9.81) \times 0.5$$

$$Fa = 40 \text{ N}$$

$$\text{Total Tractive Effort} = RR + GR + Fa$$

$$TTE = 11.772 + 68.399 + 40$$

$$TTE = 120.171 \text{ N}$$

Torque Required:

$$T = Rf \times TTE \times R_{wheel}$$

$$T = 0.1 \times 120.171 \times 0.02$$

$$T = 0.24 \text{ Nm}$$

## 5. Simulink modelling in MATLAB

### 5.1. MATLAB

MATLAB is a high-performance software that is commonly used for technical computing by the integration of visualization & programming, MATLAB helps to create an easy user-friendly environment where the mathematical notations are used to express the problems and solutions. This software is used for the development of required algorithms, computation and maths [20].

MATLAB is built on the base of MATLAB scripting language. These common uses of the MATLAB are, it helps to the deployment of Command Window in an interactive mathematical shell [20].

### 5.2. SIMULINK

Simulink is a sub tool of MATLAB which consists of a block environment for the different domain of simulation & Model-Based Design. It also supports the system-level design, auto code generation, simulation, continuous test & validation of embedded systems. Simulink provides a changeable various type of block libraries, graphical editor, and solvers for system modelling and simulating [21]. It is integrated with MATLAB software, enables to incorporate with MATLAB algorithms and export the simulation output to MATLAB for analysis [21].

### 5.3. Mobile Robotics Simulation Toolbox

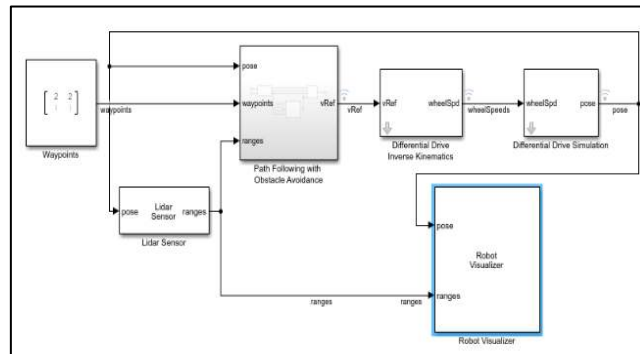
Mobile Robotics Simulation Toolbox is toolbox available in built in MATLAB which provides utilities for robot simulation and robot algorithm development, This toolbox consists of different 2D kinematic models for the robot geometries such as differential drive model, three & four wheeled vehicles model along with forward kinematics & inverse kinematics, Configurable lidar, obstacles, and simulators, Visualization of robotic vehicles and occupancy maps [22].

### 5.4. Navigation Toolbox

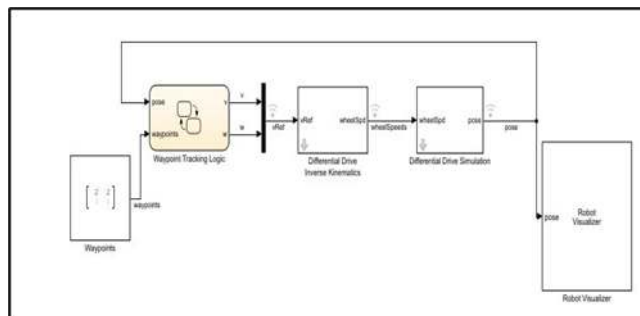
MATLAB consists of Navigation Toolbox this toolbox gives different algorithms and analysis tools. These tools are useful while designing of motion planning and navigation. This toolbox also consists of a sampling-based path-planners. The navigation toolbox also has various sensor models &

algorithms for estimation of motion. By using navigation toolbox we can create 2D map representations using our own data or generate maps using the simultaneous localization and mapping (SLAM) algorithms available in the toolbox. We can generate metrics for compare optimum path and performance. The SLAM map builder app help to visualize and debug map generation. It helps to test algorithms by deploying them directly to hardware [24]

**6. Simulation model**



**Figure 4.** Simulation model for Vector Field Histogram

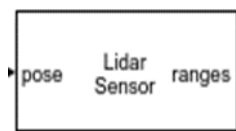


**Figure 5.** Simulation Model for Supervisory Control logic

Description of Each block given below:

*6.1. LIDAR Sensor block*

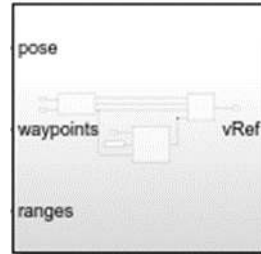
It uses to get distance information from the map, this block provides actual position of AGV to path following and obstacle avoiding block. LIDAR gives the distance from 180 angles. For simulation purpose, we take this block to get information like LIDAR.



**Figure 6.** LIDAR

*6.2. Path Following with Obstacle Avoidance*

This block consists of a Pure Pursuit algorithm and VHF which helps to follow the path and an obstacle avoidance this block gets information from LIDAR and compare it with reference location



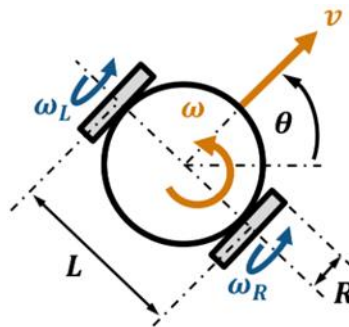
and makes the decision to avoid obstacles. This block also consists of Vector Field Histogram, The Vector Field Histogram (VFH) block help AGV to avoid obstacles, VFH is based on range sensor data [9]. Given a range of sensor reading in terms of ranges and angles, and a target direction to drive toward, the VFH controller gives an obstacle-free steering direction [23].

**Figure 7.** Path Following with Obstacle Avoidance

### 6.3. Differential Drive Inverse Kinematics

This block consists of a differential drive mechanism. kinematics is shown below.

Kinematic Model:



**Figure 8.** Kinematic Model

This AGV has two independently driven wheels which can be used to control forward and angular velocity.

This block has input Left and right wheel speeds  $\omega_L$  and  $\omega_R$ , in rad/s and output give in the form of Linear velocity  $v$ , in m/s Angular velocity  $\omega$ , in rad/s.

Forward Kinematics:

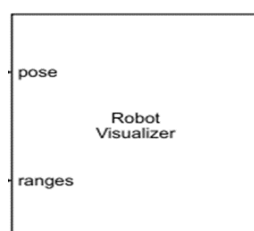
$$v = R(\omega_R + \omega_L), \quad \omega = \frac{L}{2R}(\omega_R - \omega_L)$$

Inverse Kinematics:

$$\omega_L = \frac{1}{R} \left( v - \frac{\omega L}{2} \right), \quad \omega_R = \frac{1}{R} \left( v + \frac{\omega L}{2} \right)$$

### 6.4. Robot Visualizer

Robot visualizer block helps to visualize robot simulation in a 2d map.

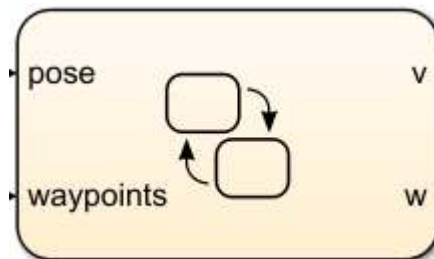




**Figure 9.** Robot Visualizer

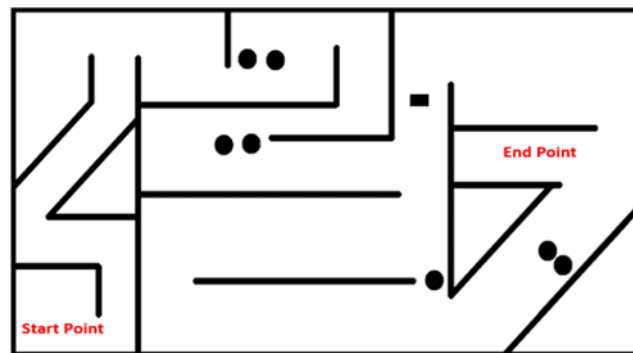
### 6.5. Waypoint Tracking Logic

The Waypoint Follower block helps to follow a set of waypoints for the vehicle using a look ahead point. The block calculates the look ahead point, desired heading, and desired yaw given a UAV position, a set of waypoints, and a lookahead distance.

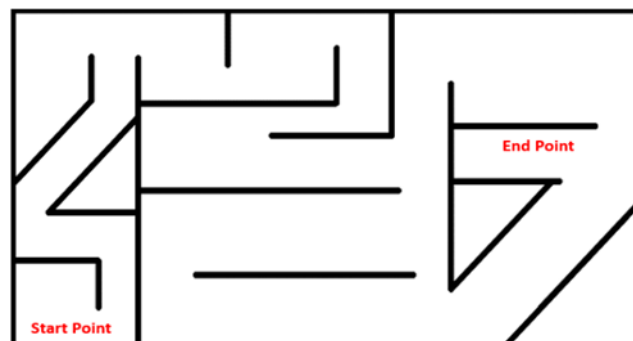
**Figure 10.** Waypoint Tracking Logic Block

## 7. Testing

For testing, we created two maps first map with obstacles and second map without obstacles.

**Figure 11.** Obstacle Map

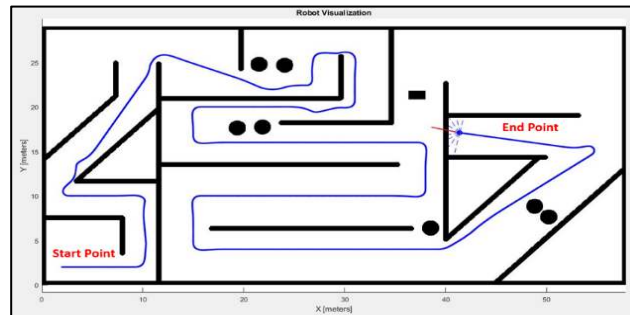
Here we created a path for AGV from start to end in this path we introduce obstacles to check the behaviour of AGV with Vector Field Histogram and Supervisory Control logic, In this map circular section act as an obstacle. To check obstacle avoidance AGV must go away from this obstacle and need to reach the endpoint.

**Figure 12.** Map Without obstacles

Above figure 12 shows map without obstacles, This map is created to check the difference between the trajectory of AVG going from the start point to the endpoint.

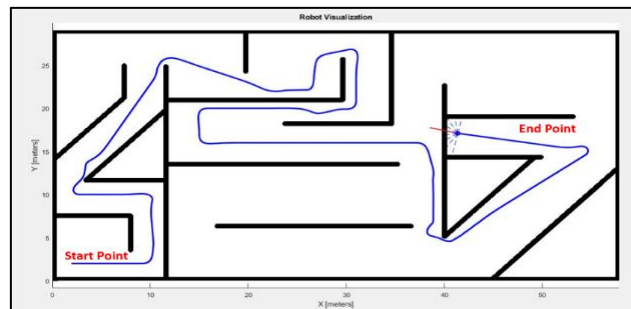
## 8. Result

### 8.1. Trajectory by Vector Field Histogram (VFH):



**Figure 13.** Trajectory of AGV With Obstacles using VFH.

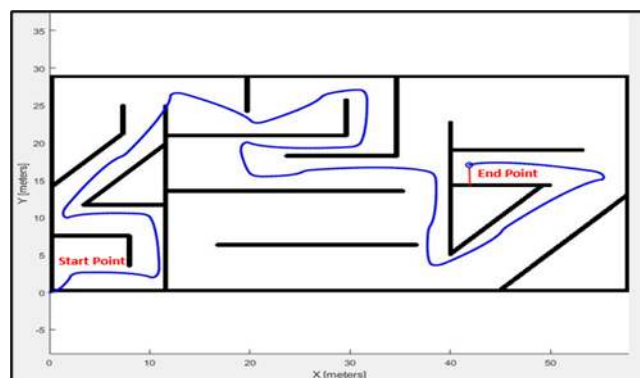
As shown in Figure 13 When an obstacle comes in the path of an automated guided vehicle sensor check the surrounding for the alternate path by creating a transient point. In the above case, it created a transient point at the right side and a new path is generated. Again it comes on its original path after avoiding the obstacle and reaches the destination. This shows the behaviour of a simulator is correct when faced against obstacles.



**Figure 14.** Trajectory of AGV Without Obstacles using VFH.

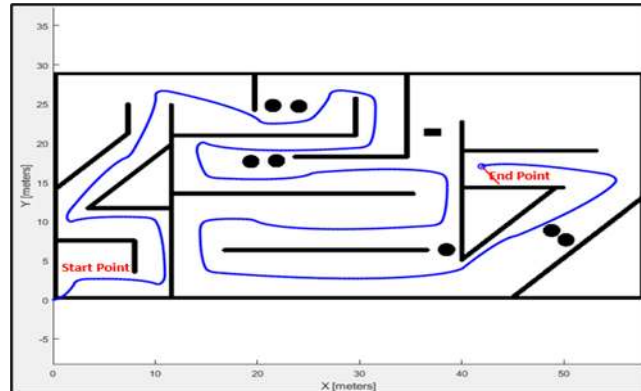
As shown in Figure 14 When there is no obstacle in path AGV senses surrounding and creates minimum distance path to reach the destination.

### 8.2. Trajectory by Supervisory Control logic



**Figure 15.** Trajectory of AGV Without Obstacles using Supervisory Control.

Figure 15 shows the trajectory of AGV with Supervisory Control logic for a map without obstacles vehicle follow present waypoint and reach to endpoint.



**Figure 16.** Trajectory of AGV With Obstacles using Supervisory Control.

Figure.16 shows the trajectory followed by the AGV for the Supervisory Control logic for the map with obstacles vehicle follow preset waypoint and reach to the endpoint.

From Figure13, 14, 15 and 16 we can see the trajectory generated by VFH is a straight line. For supervisory control logic we need to provide waypoint to reach the final destination, therefore it is complicated. Supervisory control logic has the drawback of obstacle avoidance, also this logic is not able to recognize obstacle in the path. On other hand vector field histogram needs only final destination it will automatically generate waypoints and reach the final destination with avoiding obstacles.

## 9. Conclusion

The paper describes a simulation package NAVIGATION TOOLBOX of SIMULINK for AGV that can show the motion of AGV operating with the LIDAR sensor within a map containing specified obstacle. The implementation of the obstacle avoiding problem was successful in simulation at different levels. The example showed that the Vector Field Histogram gives better trajectory and obstacle avoiding ability as compared with supervisory control logic.

## References

- [1] S. Kumar Das 2016 Design and Methodology of Automated Guided Vehicle-A Review *IOSR Journal of Mechanical and Civil Engineering* **03** 29-35
- [2] V. J. Lumelsky and A. A. Stepanov 1987 Path-planning strategies for a point mobile automaton moving amidst unknown obstacles of arbitrary shape *Algorithmica* **2** 403
- [3] J. Borenstein and Y. Koren 1991 Te vector feld histogram—fast obstacle avoidance for mobile robots,” *IEEE Transactions on Robotics and Automation* *IEEE Transactions on Robotics and Automation* **7** 278
- [4] I. Ulrich and J. Borenstein 1998 VFH+: reliable obstacle avoidance for fast mobile robots *IEEE International Conference on Robotics and Automation* **98** 1572
- [5] I. Ulrich and J. Borenstein 2000 VFH\*: local obstacle avoidance with look-ahead verification *IEEE International Conference on Robotics and Automation* **100** 2505
- [6] O. Khatib 1985 Real-time obstacle avoidance for manipulators and mobile robots *IEEE International Conference on Robotics and Automation* **85** 500.

- [7] A. Oustaloup, B. Orsoni, P. Melchior, and H. Linares 2003 Path planning by fractional differentiation *Robotica* **21(1)** 59-69.
- [8] S. J. Anderson, S. C. Peters, T. E. Pilutti, and K. Iagnemma 2010 *International Journal of Vehicle Autonomous Systems* **8(2-4)** 190-216.
- [9] J. Minguez and L. Montano 2000 An optimal-control-based framework for trajectory planning, threat assessment, and semi-autonomous control of passenger vehicles in hazard avoidance Scenarios *International Conference on Intelligent Robots and Systems* 2094-2100.
- [10] Minguez J, Osuna J and Montano L 2004 A “divide and conquer” strategy Based on situations to achieve reactive collision avoidance in troublesome scenarios *International Conference on Robotics and Automation* 3855-3862.
- [11] Durham J and Bullo F 2008 Smooth nearness-diagram navigation *International Conference on Intelligent Robots and Systems, France* 690– 695.
- [12] Mujahed M and Jaddu H 2012 Smooth and safe Nearness Diagram (SSND) Navigation for autonomous mobile robots *Advanced Materials Research*, 403-408, 4718-4726.
- [13] V. Sezer and M. Gokasan 2012 A novel obstacle avoidance algorithm: “Follow the gap method” *Robotics and Autonomous Systems* **60(9)** 1123-1134.
- [14] Park J, Kwak H, Kang Y and Kim D 2016 Advanced Fuzzy Potential Field Method for Mobile Robot Obstacle Avoidance *Computational Intelligence and Neuroscience* 2016.
- [15] Takagi T and Sugeno M 1985 Fuzzy identification of systems and its applications to modelling and control *IEEE Transactions on Systems, Man, and Cybernetics* **15(1)** 116-132.
- [16] Adams V and Askenazi A 1999 Building Better Products with Finite Element Analysis *Building Better Products with Finite Element Analysis*, Onword press.
- [17] <https://www.robotistan.com/tf-mini-lidartof-laser-range-sensor>.
- [18] <http://webdebbie3d.com>
- [19] <https://www.instructables.com/id/Tutorial-for-MD-L298-Motor-Driver-Module>
- [20] <https://www.cleverism.com/skills-and-tools/matlab>
- [21] <https://de.mathworks.com/help/simulink/getting-started-with-simulink.html>
- [22] Fixed bugs in Robot Detector with empty map, and disconnected lines i• mathworks, <https://github.com/mathworks-robotics/mobile-robotics-simulation-toolbox/commit/d74d255a702babe3e80bd8bdda3e33105ec83d9>
- [23] P. Pursuit, Avoid obstacles using vector field histogram - Simulink- MathWorks, France <https://fr.mathworks.com/help/nav/ref/vectorfieldhistogram.html>
- [24] Get Started with Navigation Toolbox, <https://www.mathworks.com/help/nav/getting-started-with-navigation-toolbox.html>