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Automated Guided Vehicle System with Collision Avoidance and Navigation in Warehouse Environments

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Abstract - *In today's world, automation is being introduced as a necessary requirement in every industry, as human error has a negative effect on safety, efficiency and quality. Warehouse logistics is such a domain where automation is implemented using Automated Guided Vehicle (AGVs). The main challenge in these systems is maintaining flexibility, having an efficient routing system, and creating a responsive collision avoidance system. The main focus of this system is to make an AGV with a simple but effective routing system, reducing cost, and increasing flexibility. This study focuses on finding a solution for routing and in-house traversal, and also implementing a collision avoidance system which can detect animate/inanimate objects and react accordingly.*

Key Words: **Automated Guided Vehicle, Obstacle detection, Collision Avoidance, Navigation, Infrared Sensor, Ultrasonic Sensor, Raspberry Pi.**

1. INTRODUCTION

An automated guided vehicle (AGV) is a mobile robot that follows markers or wires in the floor, or uses vision or lasers. They are most often used in industrial applications to move materials around a manufacturing facility or a warehouse.

Automated guided vehicles increase efficiency and reduce costs by helping to automate a manufacturing facility or warehouse. Automated guided vehicles are employed in nearly every industry including pulp, paper, metals, newspaper, and general manufacturing. Transporting materials such as food, linen or medicine in hospitals is also done. Improved product handling and speed can be achieved with the implementation of an Automated Guided Vehicle, AGV.

AGV applications are seemingly endless as capacities can range from just a few kilograms to hundreds of tons. The aim of the project is to design and fabricate such automated guided vehicle.

Early AGVs have been introduced in 1954. They are used to transport material from one point to another, without an accompanying operator The use of AGV increases flexibility, as it chooses the most efficient path from a number of options. [1]

1.1 Need

Automated guided vehicle has been developed to reduce human interference in industrial processes as AGV coordinates with the software technology. AGV depends on sensors to recognize obstacles and to get to destination by finding new path. The need is to develop an AGV which will be able to transport objects in a warehouse or similar environment in an autonomous manner.

1.2 Objectives

- To make an attempt to create an AGV system with minim
- Minimum dependency on pre-installed infrastructure like magnetic tapes, QR codes.
- Versatile nature of system so that it can be used in multiple environments with few changes/upgrades.
- System operations in a number of environments including those with exposure to extreme temperatures, gases, chemicals, sharp objects, or biological contaminants.
- System should work continuously around the clock without break.
- The damaged AGV can be repaired or replaced with ease.
- Develop efficient collision avoidance and path detection techniques.
- Eliminate manual work in industrial processes
- Affordable price for small industries

2. BACKGROUND

In this section we will introduce and discuss the technologies use to create the AGV system.

2.1 Sensors

Sensors are the basic source of data in the system. Sensors are electronic devices capable of taking input from the surrounding and convert it to electronic signals. In proposed AGV system, following sensors will be used for obstacle detection and collision avoidance.

Ultrasonic sensor: This sensor is a distance measuring sensor. It works on the principle of emitted and reflected sound waves.

Infrared sensor: This sensor is capable of detecting presence/motion of an object. It is an optical sensor, working on light wave principles.

2.3 Raspberry Pi (Microprocessor)

A microprocessor is a single core computer system which is capable of controlling the sensors and various such devices. It is responsible for processing the data gathered by sensors, and also for sensing appropriate commands to the actuator (Motor).

In the proposed system, Raspberry Pi microprocessor is used. It is a portable small board computer, widely used in robotics and research projects. Out of various available models, Pi 3 B+ (introduced in 2018) is chosen for the proposed system. It has a processing speed of 1.4 GHz, and 1 GB of RAM. SD card is used to store the operating system and program memory. It has Wi-Fi, Bluetooth and USB boot capabilities.

2.4 Raspbian OS

Raspbian is a Debain-based OS for Raspberry Pi. It is a free OS, and recommended by the Rasberry Pi Foundation for normal use. The OS is installed on a formatted SD card. It has many in-built software and packages for programming and hence is an easy to use OS or the proposed solution.

Fig-1: Raspberry Pi 3 Model B+

3. EXISTING SYSTEMS

In this section, existing technologies and solutions are discussed for navigation and/or obstacle detection.

3.1 Using Magnetic Strip

The magnetic strip navigation technology is similar to electromagnetic navigation. The difference is that the magnetic strip is placed on the road surface instead of embedding the metal line under the ground, and the magnetic strip sensing signal is used to guide.

AGV positioning is accurate, the laying, changing or expanding of the path is relatively easy compared to electromagnetic navigation. The ribbon guide is to paste the ribbon or paint on the ground, and the image signal recognition by the on-board optical sensor is used to realize the guidance. Since the ribbon is easily contaminated and destroyed, the environment is high and the positioning accuracy is low, so the application is also very limited.

3.2 Using QR Code

The principle of two-dimensional code navigation is that the AGV scans the two-dimensional code laid on the ground through the camera, and obtains the current position information by analyzing the two-dimensional code information. Two-dimensional code navigation is often combined with inertial navigation for precise positioning. Accurate positioning, small and flexible, easy to lay and change paths, easy to control communication, no interference to sound and light.

3.3 Laser Reflector Navigation

It is the installation of a precisely positioned reflector around the AGV path, which is mounted on the AGV body. The laser scanner emits a laser beam while walking with the AGV and the emitted laser beam is directly reflected back by a plurality of sets of reflectors laid along the AGV travel path, and the trigger controller records the angle at which the rotating laser head encounters the reflector. Based on these angular values, the controller matches the actual position of the set of reflectors to calculate the absolute coordinates of the AGV. Based on this principle, very precise laser guidance is achieved.

3.4 Visual Navigation

Visual navigation is a method of obtaining navigation through the AGV vehicle vision sensor to obtain image information around the running area. The hardware needs a down-view camera, a fill light, a hood, and the like to support the implementation of the navigation method. In this way, the AGV captures the ground texture by the camera during the moving process to automatically construct the map, and then compares the ground texture information acquired during the running with the texture image in the self-built map to estimate the current pose of the mobile robot. To achieve the positioning of mobile robots. The advantages of visual texture navigation are lower hardware cost and accurate positioning.

4. PROPOSED SOLUTION

The proposed solution will consist of an AGV which will have sensors attached to sense the presence/absence of an obstacle. This data will be given to the microprocessor which will check the signal and take appropriate decision to stop the vehicle, slow down the vehicle, or to let the motion continue, according the programming done. The microprocessor will send the signal to the motors accordingly to carry out the command.

The core obstacle detection setup will consist of 3 sensors, 2 IR sensors (calibrated for short and long range), and one ultrasonic sensor. IR sensor will detect the obstacle, while Ultrasonic sensor will help to find out the distance from the obstacle.

Considering that the AGV is in motion at maximum speed. If long range IR sensor detects obstacle, it will send a signal to microprocessor and the speed of the AGV will be reduced. Now if Short range IR sensor too detects obstacle, this means the obstacle is nearing critical distance (distance after which if a black body object moves ahead, collision is imminent). In this case, the AGV stops motion completely.

If only the Long range IR sensor detects the object and not the Short range IR, the AGV keeps moving at reduced speed.

For objects moving across the detection range, the AGV will behave in the same way, i.e. until an object is in Long range IRs range, AGV will move at reduced speed, while in Short range IRs range, it will remain at its position.

For navigation, a number of methods were studied, like Natural navigation using SLAM [2], RFID based navigation [3], etc. The implementation section discusses more about it.

In SLAM (Simultaneous Localization and Mapping), the AGV is manually made to move through the entire warehouse, and using laser sensors, or Camera module, the entire area is scanned and stored. A base map of the same warehouse is preloaded in the system. The SLAM algorithm is such, that is compared the scanned map to the actual map and finds out its own position and keeps improving the scanned map. [2]

RFID navigation consists of an RF reader module on the AGV. It can transmit and receive signals. The other part is RF tags, which will be the responders which will signify locations. The communication between tags and reader will help to find out location of AGV at all times. For navigation, the reader on AGV keeps reading the tags till it reads tag which is at the destination. As the location of tags and the setup is known to the programmer, the AGV can be programmed to move in a particular direction as per the currently scanned tag and the destination tag. [3]

5. IMPLEMENTATION AND RELATED RESEARCH

Implementation section consists of the work done for creating obstacle detection system, and also navigation system.

5.1 Obstacle detection and Collision Avoidance

For obstacle detection, two sensors are used, infrared proximity sensor and ultrasonic distance sensor. These two sensors are used to gather data about if an object is in their range, and what is its approximate distance, respectively. The two sensors used are interfaced with Raspberry Pi 3B+ microprocessor. The microprocessor is programmed to acquire the data from sensors, convert it to the required format and then take a decision. For testing purpose, 5V DC motors are used for motion. The control of these will be given to Raspberry Pi, with the help off a motor driver L293D.

The process of interfacing and combining these is explained as follows;

5.1.1 Ultrasonic sensor interfacing

We are using Ultrasonic sensor HC-SR04 for distance measurement. The sensor works on basic principle of sound waves, the sensor gets a trigger from the microprocessor, it produces a sound wave, the wave bounces off the object and gets reflected. Then the receiver or ECHO pin detects the reflected wave.

With programming, the start and end time of the pulse is recorded, and as the speed of sound is known, the distance between the object and the sensor can be known (which is half the distance travelled by the wave). This sensor has a higher range, but low accuracy, because sound waves bounce on any surface and the there is no way to know exactly how the waves are returning.

Also, when the obstacle is moving, the sensor tends to give erratic readings after the first few correct readings. This sensor has a slightly complicated setup, as a few resistors are needed to adjust the voltage and also to protect the sensor from burning out.

Fig-2: Ultrasonic Sensor HC-SR04

5.1.2 Infrared sensor interfacing

The sensor produces the output as HIGH or LOW (0 or 1, digital output). When the object is in range the result is 0 while the object is away the output is 1. The working of the sensor is subject to light conditions. The sensitivity of the sensor is also subject to the size of an object, for eg: a large object like a box gets detected at a distance of approximately 15-17 cm, but a thin object like a pen gets detected at a much closer distance.

The sensor actually produces an analog voltage as output which is subject to the objects distance, but is converted to digital output. It was also found that the detection range of the sensor can be altered to some extent using the adjustment screw.

To acquire actual distance measurements, firstly the digital output (0 or 1) has to be converted to analog output (voltage). For this, an A.D.C. (analog to digital converter) can be used. (e.g.: M3008 ADC). If this is not done, the sensor can still be used to detect the presence of an object. But the distance cannot be found.

Fig-3: Infrared Sensor E18-D80NK

5.1.3 Motor Interfacing

The AGV wheels will be driven by 5V DC motors, which will be controlled by the Raspberry Pi microcontroller.
For interfacing the motor, a driver module is needed. We have used the L293D motor driver. The motor is connected to the driver, and the driver to Raspberry Pi. Also a power source is needed. (In our case of testing we took power from raspberry pi itself). For controlling speed of motor, pulse width modulation technique is used. PWM is implemented in program using inbuilt library GPIO.PWM in Python/Raspbian OS.

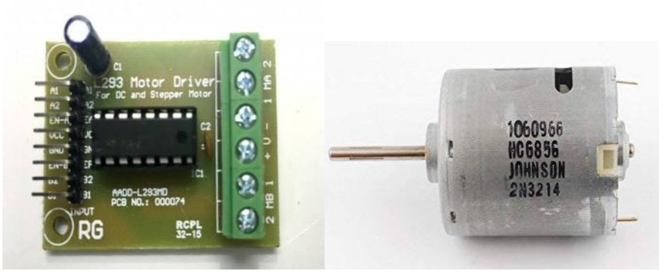

Fig-4: L293D Motor driver and 5V DC Motor

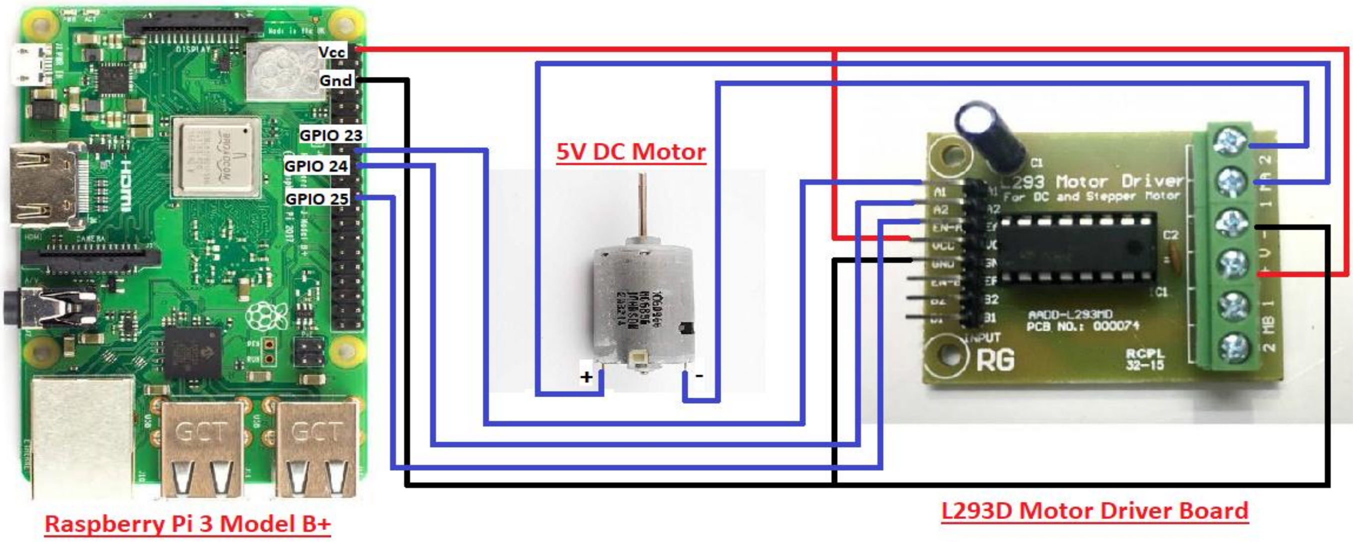

Fig-5: Motor interfacing connection diagram

5.1.4 Combination

An attempt was made to combine sensors and motor to work in unison. 2 IR sensors (Calibrated for long and short range), Ultrasonic sensor, and 5V motor were connected to Raspberry Pi, and were programmed according to requirements.

The working is as follows,

- Long range IR detects obstacle and lowers speed.
- Short range IR detects obstacle and stops vehicle, triggers US sensor.
- US sensor is activated and distance is measured.

If obstacle moves away, the motor starts working again at low or high speed according to proximity. Also, short range infrared sensors MAY be setup on the corners (front and back) which will help in parking, charging, and extreme proximity scenarios.

5.2 Navigation System for AGV

There are various methodologies that can be used for the navigation of an AGV. Various navigation systems are already into existence such as SLAM based navigation, RFID based navigation etc. The proposed navigation system relies on GRID based navigation.

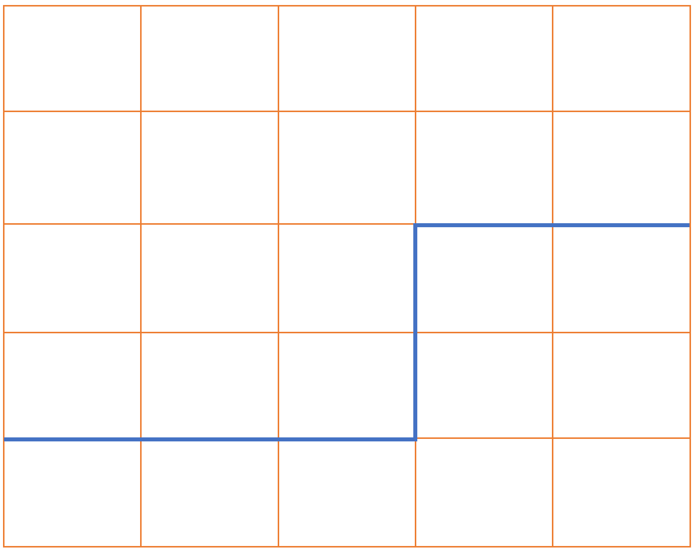

Fig-6: Grid and path

Let us assume that the warehouse is planned in the form of multiple fixed sized girds. The orange lines represent the pathway through which the AGV will be able to travel. For reaching the destination the AGV has to go 5 Units right and 2 Units upward (as per the diagram).

Suppose we denote going up as 'u' and right as 'r', the path from source to destination will be as –
rrr uu rr

We can also say, total number of possible paths can be calculated as –

$$\frac{10!}{5!\,5!}$$

Therefore to move x units in one direction and y units in another perpendicular direction to reach the destination, a AGV has -

$$\frac{(x+y)!}{x!\,y!}$$

Ways. An important thing that should be kept in mind is that, the ways are still less when more than one AGV is used as the path allotted to an AGV is subject to some stipulations.

5.3 Algorithm

The process of driving to a destination grid always follows the same 5 – step algorithm:

1. Calculate the path
2. Turn towards the direction of the next tile
3. Start driving and wait for line crossing events to happen
4. Determine which grid has the AGV arrived in
5. Finally, determine whether the robot has reached the destination grid or not.

This algorithm is shown in the figure below –

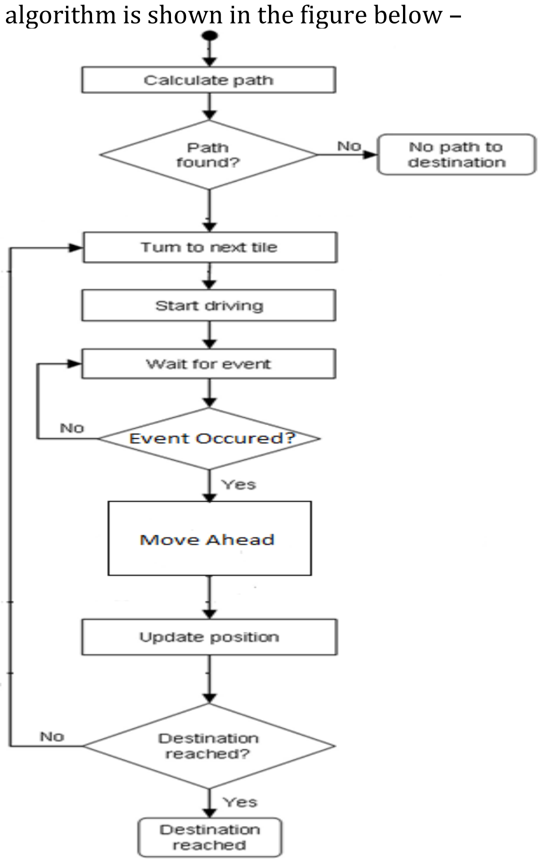

Fig-7: Flowchart for navigation algorithm

6. ROUGH MODEL/BLOCK DIAGRAM OF AGV

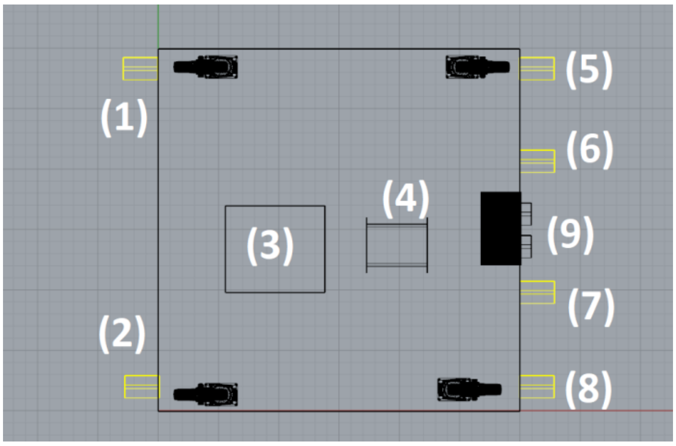

Fig-8: AGV with sensor setup

1, 2, 5, 6, 8 → Short Range IR sensors
7 → Long Range IR sensor
3 → Raspberry Pi Microprocessor
4 → Motor driver

This is a rough idea of the top view of AGV prototype and its components. There are 4 Short range IR sensors attached on the four corners of AGV. These will be useful in cases where the object isn't exactly in front of the central sensors, and also during parking or close proximity scenarios. In the front of the AGV, in the centre there are 2 IR sensors, one long range and another short range. And also there is an Ultrasonic sensor to find distance from object in front.

7. FUTURE SCOPE

The system can be upgraded with better hardware/sensors, with more accuracy and range. Also, some hardware can be added to improve obstacle detection, like a camera module, which will use image processing techniques to recognize objects.

Camera and image processing will help to differentiate between significant and trivial obstacles, while finding out their distance too. This can remove the system's dependency on sensors to a large scale.

An additional functionality which could be added is a charging station, where a rechargeable battery used on the AGV can be charged.

Furthermore, the system can be upgraded to multiple AGV system, where the AGVs will communicate can each other and efficient path decision can be done

8. CONCLUSION

Automation in the form of AGV in warehouses can be very efficient and reduce time and manual efforts required. The proposed solution can help in making such an AGV system which will successfully avoid collisions, and also carry out point-to-point transport of goods.

With more upgrades in technology and algorithm, this system can commendably perform in AGV based in-house logistic systems in warehouses.

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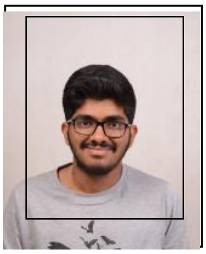

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