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DESIGN AND CONTROL OF LINE FOLLOWER AUTOMATED GUIDED VEHICLE

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Abstract— Development of automated guided vehicle plays a key role in engineering industries to improve the material handling technique for recent years. In this paper, the focus is on the design and control of line follower automated guided vehicle (AGV) systems. Obstacle detecting and avoiding Robot is designed which can detect obstacles in its path and maneuver around them without any collision. It is a robot vehicle that works on Arduino MEGA 2560 Microcontroller and employs distance sensors to detect obstacles and uses IR array to follow the line. Being a fully autonomous line follower robot, it successfully maneuvered in unknown environments without any accident. we have developed a prototype of an AGV which follows a given line on a flat surface with the help of dc motors and 4-wheel Mecanum drive. Force analysis is done for omnidirectional movement. The hardware used are generally available and economical which makes the robot easily replicable.

Keywords— AGV, Automation, 4-wheel Mecanum Assembly, line follower, Arduino, obstacle detection.

1. INTRODUCTION

Mobile robots' technical implementations are attracting continuous development. These implementations are widely used for industries, transportation and specific task. The drive, storage, protection and control of material throughout the manufacturing and distribution process can be done by mobile robot [1]. Effective material handling is the most vital part of manufacturing and distribution operation; without it final product cannot turn into profit. The handling of material must be performed safely, efficiently, at low cost in timely manner, accurately without damage to the material. The main requirements of an autonomous mobile robot are an ability to move through the environment in order to perform its navigation and task. Mobile robots' performance should have good mobility and maneuverability. These capabilities mainly depend on the type of wheels and their control [2]. Four wheels Mecanum design provides Omni-directional movement for a robot without needing any steering system and these robot ability systems to move directly in any direction from any configuration. These mechanisms are called by holonomic constraint which have ability to travel in every direction under any orientation [3-4]. The purpose of this paper is to advise the reader about different material handling solution that include AGV and autonomous mobile robot with different application of line follower AGV [5]. A line follower automated guided vehicle is a programmable mobile vehicle used in industrial application to move materials around a manufacturing unit using obstacle avoidance techniques [6].

2. WHAT IS LINE FOLLOWER AGV?

AGV have to make the system automatic by selecting proper path. The central processing system of AGV is gives the direction command and speed command. For the pre-defined manufacturing environment, the line follower robot is good option for material handling. A line follower robot is a robot which follows a pre-defined path controlled by a feedback mechanism. The path can be visible like a white line on a black surface (or vice versa) or it can be like a magnetic field tapes. The line follower robot senses a line and guide the robot to stay on path, while constantly correcting. Some of the applied applications of a line follower AGV are industrial applications were these robots can be used as automated equipment carriers in industries replacing traditional conveyer-belts with increasing speed. Some recent development of line follower is

seen in applications such floor cleaning, guidance in public places, library etc. Normally used technology in line following robot are done by using microcontrollers and IR sensor Array. The main components of line follower AGV system are

- 4-wheel Mecanum drive
- Sensors
- Microcontroller
- Drivers and Actuators

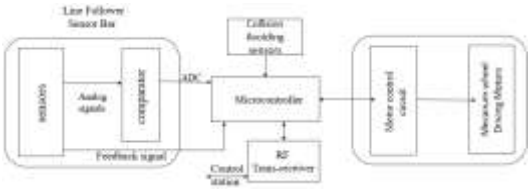

Fig. 1 Block diagram of line follower AGV

2.1 4-WHEEL MECANUM DRIVE

The special feature of Mecanum wheel is the force of the wheel is at a 45° angle to the robot instead of on one of its axes. By applying the force at an angle to the robot, it can move in any direction while keeping the front of the robot in a constant direction. Using four of Mecanum wheels provides Omni-directional movement for a vehicle without needing any steering system. Slipping is a basic problem in the Mecanum wheel as it has only one roller with a single point of contact with ground at any time. Due to the dynamics of these wheel, it can create force vectors in both the x and y-direction while only being driven in the y-direction. Positioning four Mecanum wheels, in the fashion of two mirrored pairs (in corners), allows net forces to be formed in the x, y and rotating direction.

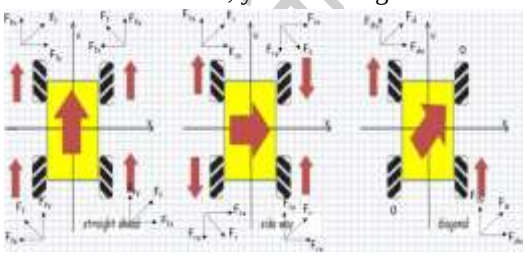

Fig. 2 Net forces formed on Mecanum Wheels

F_f, F_r, F_d= Frictional forces on Mecanum wheels in respective direction.

F_{fy}= y-component of frictional force in front direction.

F_{fx}= x-component of frictional force in front direction.

F_{ry}= y-component of frictional force in right direction.

F_{rx}= x-component of frictional force in right direction.

F_{dy}= y-component of frictional force in diagonal direction.

F_{dx}= x-component of frictional force in diagonal direction.

Net forces formed on Mecanum wheels in following directions

1.Front Direction:

F_{Nx}= 0

F_{Ny}= 4 F_{fy}

F_N= F_{Nx}+ F_{Ny}

F_N= 4F_{fy}

2.Right Direction:

F_{Nx}= 4 F_{rx}

F_{Ny}= 0

F_N= F_{Nx}+ F_{Ny}

F_N= 4 F_{rx}

3.Diagonal Direction:

F_{Nx}= 2 F_{dx}

F_{Ny}= 2 F_{dy}

F_N= F_{Nx}+ F_{Ny}

F_N= 2 F_{dx}+2 F_{dy}

In all the cases Net forces is acting on respective directions. By varying the individual wheel speed and direction of rotation we can achieve driving direction along any vector in X-Y axis.

Table I. Omni-directional Results

Sr. No	Results	
	Direction	**Explanation**
1	forward	forward direction created when all entire 4 wheels are turning to forward direction
2	backward	backward direction created when all entire 4 wheels are turning to reverse direction
3	left	sliding to left direction happen when front left and rear right wheels moving forward while front right and rear left moving backward
4	right	sliding to right direction happen when front left and

		rear right wheels moving backward while front right and rear left moving forward.
5	diagonal left	diagonal left direction created by making front left and rear right wheels moving to forward direction
6	diagonal right	diagonal right direction created by making front right and rear left wheels moving to backward direction

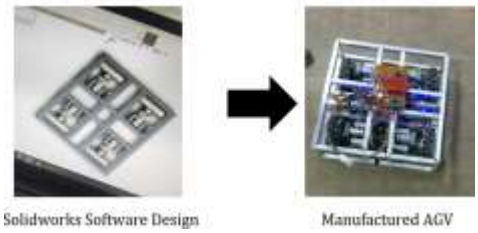

Fig. 3 Manufactured 4-wheel Mecanum AGV

2.2 SENSORS

Sensors are sophisticated devices that are used to give feedback to microcontroller and control direction of AGV.

2.2.1. ADVANCE LINE FOLLOWING SENSOR BAR

Advance Line Following Sensor Bar consists of 8 IR sensors pair. This sensor array is typically used for line following task. This array can detect any color of line which has brightness different with the background. This array is capable to operate on surface with color of Red, Green, Blue, White, Black, Gray [7]. Analog mode of sensor array allows users to get line position in the range of 0 – 70 representing the left peak sensor to the right peak sensor, with 255 if no line detected. This value is converted into voltage level ranging from 0V to 4.5V indicating 0 – 70, and 5V for 255 no line detected, where the user can get the reading through Analog-Digital Converter (ADC). By integrating PID controller with this sensor values and motor speed control, smooth accommodation of AGV is possible.

PID controller is a small piece code that allows us to find the deviation of robot to the line, and correcting the position by changing the motors speed. In this concept, we decide a set point which is on the middle of the sensor array and the robot will always try to adjust itself to center at the set point. The analog mode of LSA08 support range from 0 – 70, so 35 will be the set point value, and the target of our PID controller is to make sure, AGV achieve the position 35 in shortest time. The error of deviation formula is given by,

error = current position – set point value

Applying the PID formula to find the required speed change,

speed change =
Kp*error + Kd*(error – previous error)

where Kp and Kd are the constants. We can determine constants through experiments, while the previous error is the error before this iteration. Here we are applying PD controller, because adding Integral control does not affect the result much.

Speed of each motor from Right motor pair = base speed – speed change
Speed of each motor from Right motor pair = base speed + speed change

Fig. 4 LSA08 Sensor Array

2.2.2. ULTRASONIC SENSOR

An ultrasonic sensor is a sensor able to detect the presence of nearby obstacles without any physical contact. This sensor is used as obstacle detector in various robot. By integrating three such sensors, it is possible to detect obstacle in front side of AGV in 1-meter range Precisely using HCSR04 ultrasonic sensor. If any obstacle comes between the range of this sensors, then it gives output to the microcontroller.

Fig. 5 Ultrasonic Sensor

2.3 MICROCONTROLLER

The Microcontroller act as brain for line follower AGV. Here We have used Arduino Atmega2560 microcontroller. It has 54 digital I/O pins (of which 14 can be used as PWM outputs), 16 analog inputs, a 16 MHz crystal oscillator. Usually the line follower robot works on a closed loop PID feedback algorithm where the feedback from the line sensor is used by the controller for correcting the path of the robot. In general, the line follower robot senses the path to navigate the vehicle. The input signal is coming from LSA08 array which send to the microcontroller to analyses the current position and give instruction to the driver according to PID control program. The task of the microcontroller here is to control all four motors according to the feedback signals from LSA08 so that the robot remains on the correct path. The controller restricts motoring action according to ultrasonic sensor data. The controller is also responsible handling the different task and communication with other control system.

Fig. 6 Arduino MEGA2560

2.4 ACTUATORS AND MOTOR DRIVER

We have used actuators as four Square gearbox DC motors. For driving motors, a high value of the current is needed. Motor driver act like the current amplifier. It is use for controlling the direction and speed of the motor. The motor drive provides high current as the dc motor need when it receives low current level from circuit. By using the motor driver, a line following robot can be move in all possible directions. It fully controls the movement of the dc motor that's why it has been called as motor driver. The movement system is an important part of AGV. And its objective is how to move robot from one point to another one; to drive 4 Mecanum wheels, we have used separate dc motors for each wheel. The required direction is achieved by sending control signals to motor drive.

3. BEHAVIORS

The AGV uses some behaviors to complete its tasks. These behaviors totally dependent on sensors feedback system. Priority interrupts are used to address the precise timing requirements of AGV.

3.1 COMMUNICATION

Data processing will have done by control station and given commands has to be received by AGV, so PC is used from which commands has to be received. For this purpose, we will use RF transceivers for wireless communication between control station and AGV. RF module has a low power consumption and high sensitivity. It has integrated data filters. The operating range of RF module is -40 to85 degrees Celsius. It operates at frequency approximately equal to 2.4 GHz and uses the ISM frequency band. Also it has high accuracy.

3.2 TRACKING

Three motors speeds were defined: fast, medium, and slow. Normal navigation was done with the fast speed. If the vehicle started to stray off of the line, the microcontroller would notice a difference in the values of sensor array and decrease the appropriate motor's speed to medium. If the AGV totally left the line, the robot turns in the opposite direction of the last sensor read. For example, if the robot last saw "white" on the left-center sensor, it would turn right. For smooth movement of AGV, PID is integrated with sensor values and direction control commands.

3.3 OBSTACLE DETECTION

There is no need for humans in the automated warehouse, people could be unpredictable (unlike robots). Ultrasonic distance sensors give signals if an object is in the forward path of the predefined range. If they detect something, the robot would pause before checking to see if the obstruction is still present. For obvious reasons, the sensors should temporarily disabled when the AGV is approaching the shelves.

4. ANALYSIS BASED ON TIME

Mathematical model can able to describe the accommodation of AGV inside the manufacturing/ warehouse unit. Efficiency of AGV can be increased by decreasing drive time of AGV from loading to unloading cycle. we can assume that AGV moves with constant carrier velocity(v) throughout the environment. Also we can ignore the effect of acceleration, deceleration and other

speed difference. The time for a typical deliver cycle system of AGV depends on

1) Loading time at the pickup station
2) Travel time to the unloading station.
3) Time requires for unloading at drop off station.
4) Returning travel time.

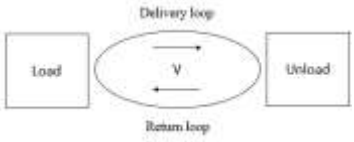

Fig. 7 Path of AGV

$$T_e = T_l + L_d/v + T_u + L_e/v$$

T_e = delivery cycle time (min/delivery).
T_l = time to load (min).
L_d = distance travelled from loading to unloading station
v = carrier velocity
T_u = time requires for unloading station
L_e = distance travelled by vehicle in returning travel.
Using the above equation, we can calculate the time require for completing a one job. so by considering this equation we can improve the ideal time of AGV.

5. AGV SAFETY SYSTEMS

AGVs must include some safety sensors and devices to avoid and proactively prevent risks. AGVs run smooth and predictable, if something does not work properly in the AGV, the Safety System will block the vehicle. Safety elements in an automated guided vehicle can be divided in two categories active safety elements and passive safety elements.

Main AGV Active Safety devices or AGV Safety Sensors are:

1) AGV collision avoidance system.
2) Contact Bumpers for stopping AGVs.
3) Emergency Stop Buttons.
4) Braking systems in conjunction with the object detection system.

While the most important Passive safety devices are:

1) Warning Lights.
2) Audible Warning/Alarm Signals.
3) Signs on AGV Vehicle.

It is very important to perform AGV Safety training to all of the staff involved in the AGV application.

6. APPLICATIONS

Autonomy is the vital factor for using AVG in different field. It will attain high degree of accuracy and precision which will lead to errorless system and improved time management.

1) Material handling: used in loading unloading station of big electronic and manufacturing industries.
2) Warehouse: used in big warehouses of company like Amazon for transporting the material.
3) Commercial: baggage transportation system inside airport, supermarket, mall, etc.
4) Energy and defense: bomb and mine mapping, retrieval and disposal nuclear plant inspection, and steam generator, pipeline inspection.
5) Medical service: handling harmful material, disposal of biological waste.

7. CONCLUSION

The use of 4-Wheel Mecanum Drive provides Omni-directional movement for vehicle without needing conventional steering mechanism. Integrating PID Controller with Line follower sensor and motor driver commands increases smoothness in movement of AGV. The cost of Manufacturing is being reduced. Sensors used are generally available and economical.

8. FUTURE SCOPE

1) Line follower type AGV can be improved by utilizing Magnetic tape following sensors.
2) one could think of the traffic control scheme so that multiple vehicles can operate in single floor efficiently with the help of live tracking.

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