International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 09, September-2020

Study on Motion Tracking Control System for AGV

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***Abstract*:-This paper presents an automatic guided vehicle (AGV) motion tracking control system. With the application of new control algorithms and the development of electronic technology, AGV is developing toward high speed, high precision, openness, intelligence, and networking, and it also puts forward higher requirements for motion control systems. To realize high-speed and high-precision position control, AGV must rely on advanced control strategies and excellent motion control systems. In this paper, according to the requirements of the control system, the Arduino/51/STM 32 microcontroller is selected as the core to design the motion control system. The paper studies the automatic guided vehicle motion tracking control system. The simulation of the motion tracking control of the intelligent robot is performed using MATLAB/Simulink. The Simulink model as well as the graph showed the AGV can reach the moving goal successfully.**

Keywords: Automated guided vehicle (AGV), Motion tracking control system, obstacle avoidance, Simulink model, PID controller.

1. INTRODUCTION

AGV is an Automatic Guide vehicle. It refers to a vehicle equipped with electromagnetic or optical automation devices that can travel on the road with safety and various transmission functions.

An automated guided vehicle is a programmable mobile vehicle that follows marked lines or ground wires. Automatic steering vehicles are robots that run on the floor of a facility run by a combination of software and sensor management systems[1].

AGV is a mobile robot that follows a specific path in the ground. They are the most widely used unmanned aerial vehicles in the industry to move materials around a manufacturing facility or warehouse. AGVs are used in almost every industry, pulp, paper, metals, newspaper and general manufacturing. Transfer of material or finished product and storage in bed is one example of the use of AGV in factories [2].The AGV's (Automated guided vehicle) began as transport devices developed to assist the manufacturing system. In the industrial robotic field, they are defined as transport vehicles driven by a computer system with different mechanical configurations . Earlier inventions on AGVs can be dated back to Barrett Electronics in 1953. One of the oldest publications on AGV can be found in. It is used to distribute materials in warehouses and to move and operate in production facilities to production areas and storage areas. It consists of different components like cranes and hoists, elevator and lifts, Conveyors, Robots, Automated Storage and Retrieval system (AS/RS)) and so on which are focused on the process of transferring something from one place to another. Utilization of components, either individually or from a combination point of view, is determined by its application or pre-assigned flexibility. Tracking is one of the most important aspects of AGV control and a prerequisite for completing accurate road tracking work. However, AGV is very indirect, making it difficult to track control challenging [3]. Many methods were proposed to solve this problem [4] and [5] proposed a linear proportional control method, [6] proposed a PID control method. This intelligent handling robot is based on the Arduino/51/STM32 microcontroller board program, to design an aluminum alloy body, multiple mounting holes on the robot chassis adding various sensors and controller, a space for the servo is also left to turn the mechanical manipulator. With the help of the engine, the robot chassis can turn smoothly to the left, right, circular, forward, and robot backward, etc. The size of the robot body part is 290mm length, 520mm height and 260mm width in thickness, where it adopts intelligent bus servos, and supports various controls, metal gears, and imported potentiometers are mounted on the arm of the robot and the robot has 6 degrees of freedom robotic arms with every joint controlled separately.

2. OBSTACLE DETECTION

In a real environment, an automated guided vehicle must avoid obstacles to go to or moving to a target. Depending on the positions of the target or the goal and the obstacle (s) relative to the automated guided vehicle, as the automated guided vehicle moves toward the target and sensors detect obstacles, it is important to control the avoiding strategy and motion control of the speed. In this paper, we use color recognition sensor to the intensity of light reflection by different colors, singletrack sensor used to When the detected object appears within the detection range, the infrared ray is reflected with sufficient intensity and the infrared receiving tube is saturated, sound sensor is the most sensitive and used to detect ambient sound intensity.

Ultrasonic sensor protecting the automated guided vehicle robot from hitting the wall, and measures the distance from the wall or other obstacles as close to the measured distance the motion control will achieve its intended goal by looking for an alternative route [7].

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When there are barriers or obstacles in the environment, the automated guided vehicle robot's response is based on sensory information of the obstacles and the targeted position.

In addition to this, sensors determine if something or an object was in the forward motion of the vehicle. They detect something and responds; the automated guided vehicle robot will pause or to find another way based on the program before checking if the obstacle is still present.

In this paper we used the most and popular algorithm is ON and OFF algorithm. The ultrasonic sensor is fixed in front of the robot this emits ultrasonic waves and measures the wave reflected from the obstacle surface to give a value corresponding to the distance of the obstacle

KINEMATIC AND DYNAMIC MODEL

A. Kinematic model

In this paper, autonomous guided vehicle robot platform considered is like a monitored mobile platform which is driven by using two motors while two standard caterpillar tracks operated by the actuators for the motion of the mobile robot, and they are placed on both sides by a mobile robot. The kinematic mode can be described as shown in Fig. 1

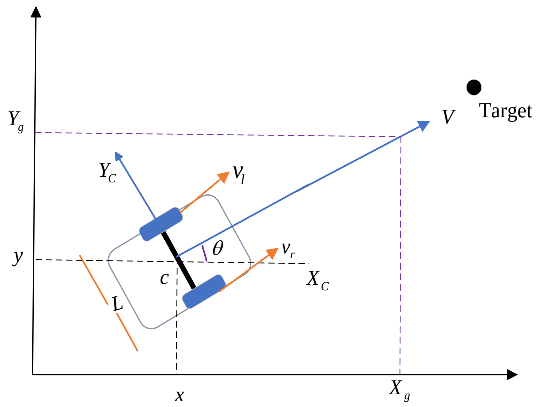

Fig.1 Kinematic motion of AGV robot.

Using this model the speed control, the kinematic responses of the automated guided vehicle robot during traveling need to be defined as, c is the center of a robot mobile platform, L is the length between two tracks, v_l and v_r denote the linear velocities of left and right track relative to the ground, respectively. It can be calculated from the equation of the left velocity (v_l) and the right velocity (v_r) of the tracks are written as:

$$v_r = \omega(r + \frac{L}{2})$$
$$v_r = \omega(r - \frac{L}{2}) \quad (1)$$

$$v_l = r\omega_l \quad (2)$$

$$\omega = \frac{d\theta}{dt} \quad (3)$$

Where ω_r and ω_i are angular velocity of the right sprocket wheel and left sprocket wheel, r is the radius of track sprocket drive wheel respectively.

The summation of linear movement velocity of the automated guided vehicle robot is calculated as follow:

$$v = \frac{v_r + v_l}{2} = \frac{r(\omega_l + \omega_r)}{2} \quad (4)$$

From the above equation (4), it is possible to say that if the spinning speed of each wheel is the same magnitude and the same direction and the automated guided vehicle robot moves straight along positive x-axes.

If the spinning speed of each wheel is having the same magnitude and opposite direction, the automated guided vehicle is at stationary. ($v = 0$).

Whereas the rotational velocity is given by

$$\omega = \frac{v_r - v_l}{L} \quad (5)$$

After tracking the speed of an automated guided vehicle, the next behavior that can be evaluated are the local coordinate of the tracked an automated guided vehicle robot in longitudinal and lateral motions during movements. Both longitudinal and lateral motion is described as follows [8]. The center position (x, y) and orientation θ of the AGV are represented by

$$\dot{x} = v\cos\theta = (\frac{v_r + v_l}{2})\cos\theta = \frac{r}{2}(\omega_r + \omega_l)\cos\theta \quad (6)$$

$$\dot{y} = v\sin\theta = (\frac{v_r + v_l}{2})\sin\theta = \frac{r}{2}(\omega_r + \omega_l)\sin\theta \quad (7)$$

$$\dot{\theta} = \omega_c = \frac{(v_r - v_l)}{L} = \frac{r(\omega_r - \omega_l)}{L} \quad (8)$$

$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \frac{r(\omega_r + \omega_l)}{2} \\ 0 \\ \frac{r(\omega_r - \omega_l)}{L} \end{bmatrix} \quad (9)$$

B. Dynamic model

Dynamic modeling of the robot is the study of motion in which forces and energies are modeled and studied. The actuator modeling is required to find the relationship between the control signal and the mechanical system input.

The motion control system of an autonomous guided vehicle can be simplified to a DC motor motion control. In modeling DC motors and in order to obtain a linear model, the hysteresis and the voltage drop across the motor brushes are neglected, the motor input voltage, v_{in} is applied to the field or armature terminals. DC motor can be modeled based on three essential electrical components: a resistor (R), an inductor (L), and a source of electromotive force (EMF), or voltage. DC motor turns electrical energy into mechanical energy and produces the torque required to move the load to the desired output position, θ or rotate with the desired output angular speed, ω. The torque produced a rotational acceleration of the rotor, depending on its rotating mass or with its inertia J, and a linear viscous damping force, b_m and the rotational speed.

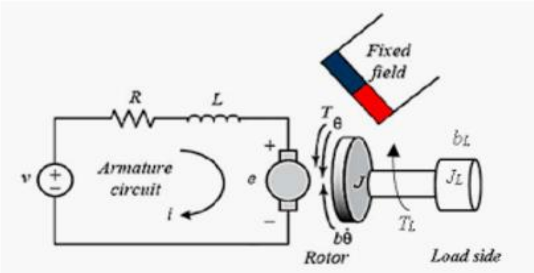

Fig. 2 Armature Controlled DC motor modeling

To deal with the two independent drive mechanisms to improve the flixebility of the AGV let's take look at the DC motor mathematical model.

From Electrical part

$$V_{in} = Ri + L_a \frac{di}{dt} + k_b \frac{d\theta}{dt} \quad (10)$$

Transfer function for DC motor using the Laplace transform, and rearranging gives:

$$V_{in}(s) = RI(s) + L_a sI(s) + k_b s\theta(s)$$
$$(L_a s + R)I(s) = V_{in}(s) - k_b s\theta(s) \quad (11)$$

From equation (11) we can express $I(s)$ as

$$I(s) = \frac{V_{in}(s) - k_b s\theta(s)}{L_a s + R} \quad (12)$$

From mechanical part

$$\tau = J_m \frac{d^2\theta}{d^2 t} + b\frac{d\theta}{dt} = k_t I \quad (13)$$

Taking Laplace transform and rearranging, gives:

$$Js^2\theta(s) + b_m s\theta(s) = k_t I(s) \quad (14)$$

Substituting (13) in equation (14) and rearranging gives:

$$V_{in}(s) - k_b s\theta(s) = (L_a s + R)\frac{J_m s^2\theta(s)}{k_t} \quad (15)$$

$$V_{in}(s) = (L_a s \frac{J_m s^2\theta(s)}{k_t} + R\frac{J_m s^2\theta(s)}{k_t}) + k_b s\theta(s) \quad (16)$$

From equation (16) the transfer function of the input voltage, $V_{in}(s)$ to the output angle, $\theta(s)$ and angular speed, $\omega(s)$ directly follows:

$$G\theta(s) = \frac{\theta(s)}{V_{in}(s)} = \frac{k_t}{s\{(L_a s + R)(J_m s + b_m) + k_t k_b)\}} \quad (17)$$

$$G\omega(s) = \frac{\omega(s)}{V_{in}(s)} = \frac{k_t}{(L_a s + R)(J_m s + b_m) + k_t k_b)} \quad (18)$$

Where R -resistance

L_a -inductance of the motor

J_m –moment of inertia

b_m –viscous coefficient referred to the motor shaft

k_t -torque constant

k_b -emf constant.

Table 1. parameter of 12V DC Motor

Parameters	Symbol	Value
Terminal voltage	V	12V
Armature resistance	R_a	0.156 Ω
Armature Inductance	L_a	0.82H
Geared motor Inertia	J_m	0.271kg.m^2
Geared motor viscous damping	b_m	0.271N/rad/sec
Back-EMF Constant	k_b	1.185V.sec/rad
Motor torque constant	k_t	1.188 Nm/A

Gear ratio n=3, Radius of the wheel=0.06m, distance between two wheels=24cm

PID motion Controller

AGV motion control often uses a PID controller, taking AGV position, speed of motor and error rate of change as the controller input, and robot position, speed of motor and direction angle as the control output. In actual systems, changes in the expected values of position, speed, and direction angle, changes in actual road conditions, deviations or changes in rotational inertia, center of gravity positions, inconsistencies between the wheels and the drive, etc. make global tuning of PID control parameters extremely difficult.

In recent years, PID control has been successfully applied to mobile robots and autonomous guided vehicles. Due to the complexity and uncertainty of the AGV operating environment, it is difficult to establish an accurate model for it, and the advantage of PID control is that it does not require the establishment of an accurate mathematical model of the controlled object. Therefore, PID control is very suitable for AGV control. In response to this problem, the corresponding PID controller is designed in this paper, which can reduce the difficulty of PID parameter tuning and generally improve the control accuracy and robustness of the system PID control is commonly used in feedback control.

Table 2. Effect of PID Parameter

Pararm eter	Rise time	Over shoot	Settling time	Steady-state Error
KP	Decrease	Increase	Small Increase	Decrease
KI	Small decrease	Increase	Increase	Large Decrease
KD	Small Decrease	Decrease	Decrease	Minor Change

(19)

The mathematical model of PID controller can be expressed relation ship between the controller input $e(t)$ and the controller output $u(t)$ by the following formula

)

$$u(t) = K_p e(t) + K_I \int_0^t e(t)dt + K_D \frac{de(t)}{dt} \quad (20)$$

Where, $u(t)$ is desired control, e, define for each task below, is the error between the desired value and the output value, K_p is the proportional gain and it depends on present error, K_I is the integrator gain and depends on the past error,

K_D is the derivative gain and depends future error and t is time. The control gains used in this research are obtained by tweaking the various values to obtain satisfactory responses[9].

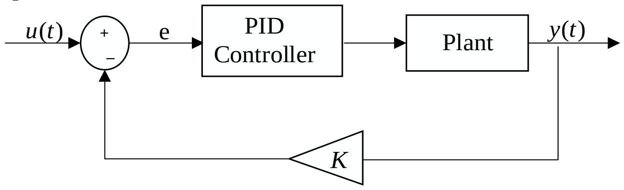

Fig. 3 Block diagram of DC Motor with PID controller.

3. TESTING AND THE RESULT OF THE SIMULATION

It is important to know the characteristics and specification parameter of the autonomous guided vehicle robot system and the DC motor to control the motion of the robot according to the speed at which it is considered as the desired linear speed motion of the AGV robot is 0.4m/s when 7.4V input is embedded to the robot for supplying electric power. Using the transfer function equation we can get the speed sensor constant volue as follows.

$$V_{out}(t) = K_{tac} * \frac{d\theta(t)}{dt}$$

$$V_{out}(t) = K_{tac} * \omega \qquad (21)$$

$$K_{tac} = \frac{V_{out}(s)}{\omega(s)}$$

Therefore K_{tac}=1.8, for $\omega = 6.666 rad/\sec$ is given as angular speed.

The robot platform we are doing with autonomous guided vehicle robot which has two driving DC motors as shown in the Simulink model of AGV robot system fig.4 We have already done the Simulink for the DC motor and running the model will get the result in the fig.5. First of all, we want to test the Simulink model of DC motor with the wheel for setting the parameter KI and KD gains to zero and then increase the value of KP gain until the loop output becomes to oscillate. KP=1, KI=0 and KD=0. The result of the simulation indicates the robots linear speed is not stable, when it is compared with the desired robot linear speed there is an error as shown in the Fig. 5 as the simulation result

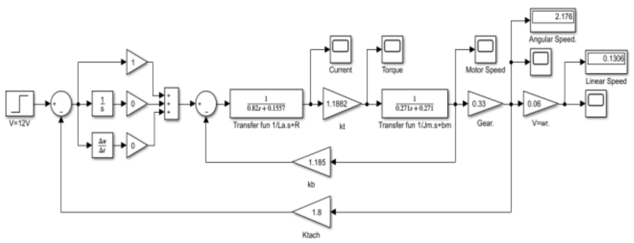

Fig. 4 Simulink test for motor with KP=1, KI=0, and KD=0

The linear speed of this Simulink response basically meets the requirement and does converge, have overshoot, have undershoot, moderate rise time and have settling time,but doesn't reach the ultimate goal and the system is not stable.

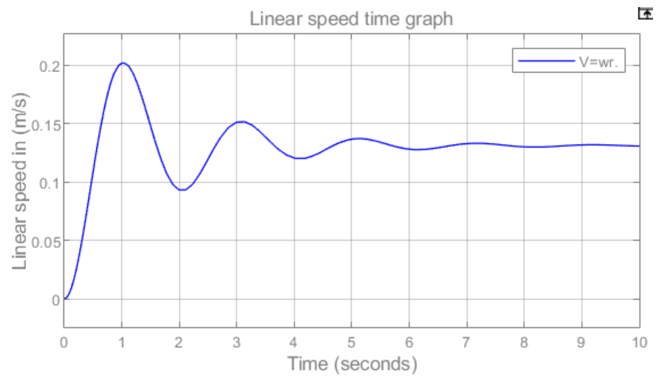

Fig. 5 Simulation result of motor with KP=1,KI=0 and KD=0

We can see the result of the simulation in fig 5. indicates that the AGV robot linear speed is equal to 0.1306 m/s. When it is compared with the desired robot linear speed, there is a difference or an error of 0.2694 m/s. There fore using manual tuner PID controller should be used in this paper to reduce this error

Second we want to use the munual tuning method of PID controller to get the desired speed effectively with K9=157.18, KI=86.22, and KD is 21.68, we can see the result of the simulation indicates that the automated guided vehicle linear speed is 0.4m/s with a little bit overshoot and it has stable as shown in the Fig. 7 below.

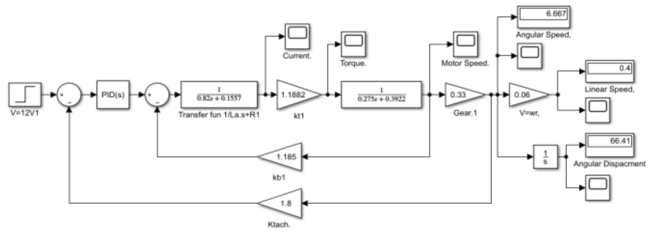

Fig. 6 AGV linear speed with KP=157.18, KI=86.22 and KD is 21.68 values of gain.

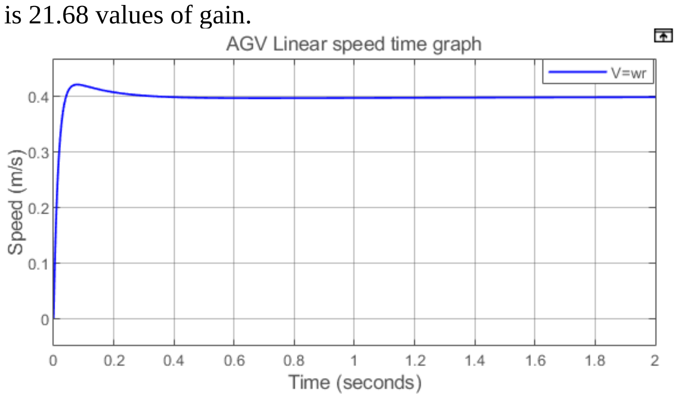

Fig. 7 Simulation graph of linear speed control

Experimental result

The motion of automated guided vehicle robot step experiments is conducted to verify the performance of our prototype. The maximum PWM generated by the motors controller the speed is 0.4m/s and this is the maximum possible speed of the AGV robot.

The master controller sends instructions to each actuator or arms through servo units. Lithium battery power supply (Li-Po battery)/2200mAh, 12V is embedded to the robot for supplying electric power.

International Journal of Engineering Research & Technology (IJERT)
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Vol. 9 Issue 09, September-2020

In this experiment laptop operator control unit or personal computer is used as a master controller, The unit can also store manipulator arm poses and display robot location, orientation and its battery life. It also displays keyboard shortcuts to operate and control the robot without using a hand controller.

As we can observe, as shown in the figure below the AGV is moving forward when there is no obstacle in front of it. When it approached the obstacle the ultrasonic sensor detects the obstacle and responds it changes its direction as attached herewith in the Fig. 8 below.

Moving forward   Turning to right

Moving backward   Turning to left

Fig. 8 Motion control system of an AGV robot

CONCLUSION

In this paper, an automated guided vehicle has been controlled of the independently driven wheels is based on a kinematic model and dynamic model. An automated guided vehicle robotic platform and kinematic based on a motion tracking system are designed. The DC Motor Simulink Modeling is tested based on DC motor parameters and PID parameters, to reduce the error; the DC motor speed is controlled by the PID controller for the AGV motion control system to the desired linear speed in a robotic platform. After controlling AGV speeds, it can move forward, backward, right, left. We have used different sensors to track the tracking control system and avoiding obstacles. In the future work, there are many tasks to be considered the goal-seeking issue, GPS can be used to find the current coordinates and assign to desired goal position coordinates. Accurate control of the heading angle and orientation can be performed using a magnetometer.

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