Automated Guided Vehicle for Carrying Carts

Kirushan T., Punsala P.P.G.P, Wimalajeewa M.H.T.N., A.G.B.P.Jayasekara
Department of electrical engineering
University of Moratuwa
Colombo, Sri Lanka.
{ kirushant.19, punsalappgp.19, wimalajeewamhtn.19, buddhikaj }@uom.lk

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I. Introduction

The growing demand for efficient and reliable transportation solutions in industrial and commercial settings is driving the development of innovative technologies, such as automated guided vehicles (AGVs). AGVs are unmanned vehicles that can navigate autonomously along predefined paths, offering a number of advantages over traditional transportation methods, including increased efficiency, reduced labor costs, and improved safety. However, conventional AGVs are typically designed to transport specific types of materials, limiting their versatility in industries such as food and beverage, where both solid and liquid materials need to be transported.

To address this challenge, we propose an AGV design capable of transporting both solid and liquid materials. It utilizes a line-following navigation system with a load type identification system and a speed controlling system, to ensure safe and efficient transportation of both solid and liquid materials. In this paper, we present a detailed overview of our AGV system design and implementation, highlighting its key features.

II. Literature Review

The project is based on designing a prototype of a tugger type Automated Guided Vehicle. So, the design will be a scaled down version of an actual AGV [1]. Designing a Tugger Automated Guided Vehicle (AGV) involves a critical synthesis of existing research and best practices. The key areas to be considered are navigation methods [2][3], load capacity, safety features, and efficiency. Previous studies have explored options with their advantages and limitations. Load capacity design should prioritize flexibility to accommodate various material handling tasks. Safety mechanisms, such as obstacle detection and collision avoidance, are paramount in AGV design to ensure a safe working environment.
Overall available designs are mostly designed to handle solid loads in industrial applications which means they follow the same speed controlling architecture for all types of loads [4].In actual sceneries, there are solid, liquid and fragile things too. Handling liquid with AGVs has unique challenges such as spillage prevention, weight distribution, and stability maintenance. There is a need to follow anti-slosh control strategies to ensure the safe and efficient transport of liquids by AGVs. So, by identifying the load type [5], our AGV will have a varying speed controlling mechanism which can handle solid, liquid, and fragile type loads in a safer manner.

TABLE 1. Summary of the review

Objectives	***Techniques so far***	***Research Gap***	***Our Design Idea***
Navigation Method	Laser guidance Line Following Guidance Barcode Guidance Magnetic Spot Guidance	Robust visual navigation	Line following guidance
Speed Control	PID Controllers Vision Based Controllers	Load type and load weight-based controlling	PID controller [4] with load type and weight-based control.
Load Type Identification	RFID Barcode QR code [5]	Hybrid approaches	QR code

The load type and the load weight-based speed controlling system are the primary areas of focus for our AGV.

III. METHODOLOGY

A. *AGV and Trailer Design*

While designing the physical structure of our AGV, we adhered to the principles of dimensional scaling, leveraging the design of existing AGVs while reducing their size to suit our specific requirements [6]. We also considered the dimensions of our chosen components and ensured force equilibrium under maximum AGV output. Additionally, we adopted a front-wheel driving mechanism to prevent rotation around the rear wheels when the tugger component is connected. This decision was driven by the realization that rear-wheel driving would lead to undesirable rotation due to the applied torque. Leveraging the calculated dimensions and variables, we meticulously constructed a 3D model of the AGV using SOLIDWORKS. Fig. 1, Fig. 2 and Fig. 3 show the structure of our AGV design.

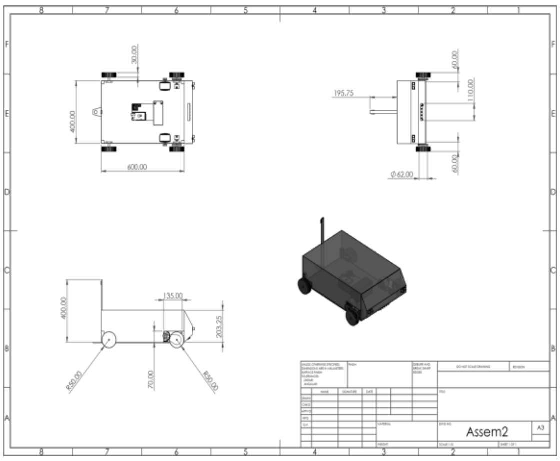

Fig. 1. The dimensions of the AGV

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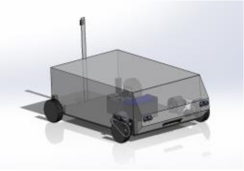

Fig. 2. Design of front part of the AGV

Fig. 1. Design of Tugger part of the AGV

The motor sizing for an AGV is a critical aspect of the design process, as it directly impacts the vehicle's performance, efficiency, and overall capabilities. The appropriate motor selection ensures that the AGV can meet its specified payload capacity, speed requirements, and gradability limitations.

To determine the required motor torque and speed for the AGV, we employed a comprehensive analysis of the vehicle's dynamics and load characteristics. Utilizing Equation (1), we calculated the total load inertia (JL), which encompasses the AGV's inertia and the inertia of the attached carts. Subsequently, we employed Equation (2) to determine the required motor speed (Vm2) based on the desired AGV velocity and the wheel diameter. Finally, we utilized Equation (6) to calculate the requisite torque(T), considering factors such as load inertia, gradeability, acceleration, and friction coefficient.

(m1 - vehicle mass, D1 - wheel outer diameter, md1 - wheel mass, n1 - number of wheels, μ -friction coefficient between wheel and floor, N - number of carts, m2 - mass of each cart, D2 - wheel outer diameter, mD2 - wheel mass, n2 - number of wheels per cart, Dp1 - primary Pulley diameter, Dp2 - secondary Pully diameter, α - Maximum angle of floor slope, V2-max speed, t1-tome to get max speed, Jv-inertia of AGV, Jc – inertia of cart, J_{Dp1}-inertia of primary pully)

$$JL = (J_V + J_C + J_{Dp2})(D_{p1}/D_{p2})^2 + J_{Dp1} \quad (1)$$

$$Vm2 = V2/(\pi D1 \times 10^{-3})(\frac{Dp2}{Dp1}) \quad (2)$$

$$F = 9.8((m1+n1\times mD1)\times(\sin\alpha + \mu\cos\alpha) + (m2+n2\times mD2)\times(\sin\alpha + \mu\cos\alpha)) \quad (3)$$

$$TL = \frac{(F \times D1 \times 10-3)}{(2\,\eta \times 0.01)\,(Dp1\,/\,Dp2)} \quad (4)$$

$$Ta = JL\,(\frac{Vm}{(9.55 \times t1)}) \quad (5)$$

$$T = (Ta + TL)(Safety\ Factor) \quad (6)$$

B. System Overview

Fig. 4 shows the overall system overview of the Automated Guided Vehicle.

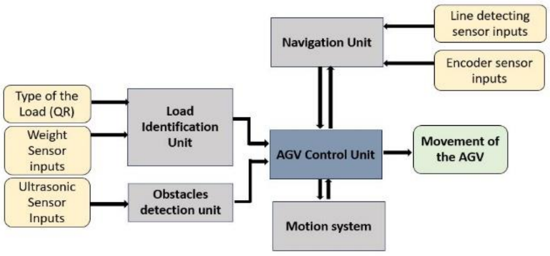

Fig. 3. System Overview

A load identification unit [5] will be used to identify the type of load which the AGV is going to carry and its weight. AGV will follow different speeds according to the load types. There is an obstacle detection unit to avoid collisions during transit. AGV will navigate with the principle of line following method. The motion of the AGV will be controlled by two DC motors which are connected to the front wheels, based on differential motor control.

IV. Results

Parameters of the AGV: -
Front part: Length -60 cm, Width – 40 cm, Height - 20 cm
Tugger part: Length -60 cm, Width -40 cm, Height – 25 cm

We have designed a simulation for the navigation of the AGV according to the developed line following algorithm. With the usage of the developed algorithm, the AGV will follow the line according to the input values from the IR sensor array. The following Fig. 5 illustrates the simulation

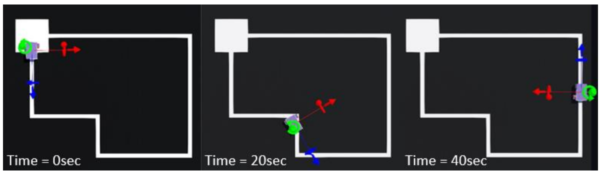

Fig. 5. Line Following Simulation in the interval of 20sec

created for this navigation process.

The simulation software 'Webots' was used in conjunction with the 'Python' programming language, to simulate and develop the algorithm.

V. Conclusion

In this paper, we have presented the AGV design capable of transporting both solid and liquid materials safely and efficiently by combining a line-following navigation system, load-type identification technology, and a speed control mechanism. We have discussed the key components and functionalities of our AGV system, including line-following algorithm simulations, the designed 3D models for the AGV and tugger components, and the load type identification method using QR codes and motion system. These elements collectively contribute to the successful transportation of materials. As we move forward, we aim to continue enhancing its capabilities and accuracy and ultimately increasing the reliability of the material transportation process.

VI. References

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