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Design & Development of Automated Guided Vehicle for Small Scale Industry

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Abstract - *In modern industrial and logistics operations, there is a growing demand for the efficient and automated movement of materials and goods within facilities. Manual material handling processes are often time-consuming, labour-intensive, and prone to errors, limiting the overall productivity and competitiveness of organizations. To address these challenges, the design of an effective and reliable Automated Guided Vehicle (AGV) system is imperative. Automated Guided Vehicles (AGVs) have become essential tools in various industries for efficient and automated material handling and logistics. The design process involves selecting suitable sensors, actuators, and control algorithms to enable autonomous navigation, obstacle detection, and precise positioning. Key considerations include safety, adaptability to different environments, and the ability to interact with other automated systems in a seamless and synchronized manner. The study also delves into the integration of AGVs into existing manufacturing and logistics processes, exploring the potential benefits in terms of increased productivity, reduced operational costs, and enhanced flexibility. Also, there are challenges and future prospects in AGV design, which highlights the ongoing advancements in this field to meet the evolving demands of industry 4.0 and the smart manufacturing landscape. The findings presented in this report contribute to the development of robust and efficient AGV systems, paving the way for improved automation and optimization of material handling operations in various industrial settings.*

Key Words: Automated movement, Material Handling, Productivity, AGV system, Design, Autonomous navigation, Obstacle detection, Safety, Enhanced Flexibility, Industry 4.0

1. INTRODUCTION

In our project, titled "Design and Development of Automated Guided Vehicle", we focus on the design and development of an Automated Guided Vehicle (AGV), a mobile robot designed to autonomously navigate through industrial environments. AGVs typically follow markers, wires embedded in the floor, or utilize advanced technologies such as vision systems or lasers for navigation. These robotic systems have gained significant traction in industrial settings, particularly in manufacturing facilities and warehouses, where they play a pivotal role in material handling operations.

The integration of AGVs into industrial workflows offers substantial benefits, including enhanced efficiency, cost reduction, and improved safety. By automating the movement of materials and goods within facilities, AGVs streamline operations, minimize manual labor, and mitigate the risk of accidents associated with human-operated machinery. This automation not only boosts productivity but also contributes to the optimization of resource utilization in material handling processes.

With the advent of Industry 4.0, the ongoing advancements in AGV technology are shaping the future of automated material handling systems. As industries continue to evolve towards smarter and more interconnected operational frameworks, the role of AGVs in facilitating seamless automation and efficiency in material handling is becoming increasingly indispensable.

1.1 Problem Statement

The primary problem is to design an AGV that can navigate autonomously and safely in complex and dynamic environments, including manufacturing plants, warehouses, and distribution centers. This AGV should be capable of performing various material handling tasks, such as transporting goods from one location to another, loading and unloading items onto/from conveyors or shelves, and interacting with other machines or equipment seamlessly.

1.2 Aim & Objectives

1. To maximize efficiency and productivity by automating repetitive and time-consuming tasks.
2. To increase flexibility by making the AGV easy to program to perform different tasks and to adapt to changes in the environment.
3. To reduce energy consumption and operating costs.
4. AGVs aim to contribute to sustainability efforts by reducing energy consumption, emissions, and waste associated with material handling operations.
5. To design a robust chassis capable of supporting the mecanum wheels and the necessary electronic components.
6. To model the kinematics of the mecanum wheels to understand their omnidirectional movement capabilities.

1.3 Scope

1. **Manufacturing:** AGVs are extensively used in manufacturing industries for material handling tasks such as transporting raw materials, components, and finished products between different stages of production lines.
2. **Warehousing and Distribution:** AGVs play a crucial role in warehouses and distribution centers for tasks such as pallet handling, order picking, and replenishment, contributing to efficient inventory management and order fulfillment.
3. **Automotive Industry:** AGVs are widely deployed in automotive manufacturing plants for tasks such as parts delivery to assembly lines, finished vehicle transportation, and intra-factory logistics.
4. **Food and Beverage Industry:** AGVs are utilized in food and beverage processing plants and distribution centers for handling pallets of raw materials, packaging materials, and finished goods, ensuring hygiene and compliance with food safety standards.
5. **Pharmaceutical Industry:** AGVs are employed in pharmaceutical manufacturing facilities and warehouses for the safe and efficient handling of sensitive materials such as active pharmaceutical ingredients (APIs) and finished drug products.
7. **E-commerce and Retail:** AGVs are increasingly used in e-commerce fulfillment centers and retail warehouses for tasks such as order picking, packing, and shipping, enabling faster order processing and delivery.
8. **Hospital and Healthcare:** AGVs find applications in hospitals and healthcare facilities for tasks such as linen and medication delivery, waste transportation, and meal distribution, improving operational efficiency and reducing manual handling risks.

1.4 Methodology

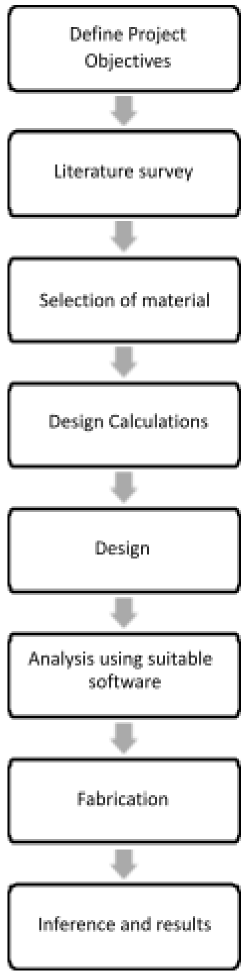

Fig -1: Methodology

2. LITERATURE SURVEY

J. Sankari, R. Imtiaz, [1] "*Automated guided vehicle(AGV) for industrial sector*", 2016.
In this studied that the importance of Automated guided vehicles in industrial sector. There are different types of AGVs such as line followers which are further divided into wire line followers, guided tape (magnetic or coloured tape). Another type is laser guided AGVs which follow Laser target navigation in which routing is made by reflective tape on walls, pole or fixed equipment. The AGV is implemented using ATMEGA 328 controller which has remarkable EPROM compared to other controllers.

Taher Deemyad, Ryan Moeller, Anish Sebastian [2] "*Chassis Design and analysis of an autonomous ground vehicle(AGV) using Genetic Algorithm*", 2020.
This paper analyzes the design of a prototype chassis for an autonomous ground vehicle (AGV). This prototype is a four-wheel powered vehicle which would be used for identifying and removal of potatoes affected by virus Y (PVY) in the field. Potato fields are fraught with rough terrain and deep irrigation ruts. Navigation of such a terrain is very challenging and demanding on the robot chassis. An optimization routine was used for finding the ideal size and material for the chassis. Seven different stress analysis were conducted to help narrow down the chassis design and material for the prototype. In addition to a general overview of the various vehicle subsystems, a detailed description of the force and stress analysis for the chassis of this vehicle is provided. All stress analysis for this chassis passed the design requirements in CAD model (SolidWorks) and has been built and tested in the field.

Merin Antony, Megha Parameswaran, et.al, [3] *"Design and Implementation of Automatic Guided Vehicle for Hospital Application"*, 2016.
With the advancements of robotic technologies, the medical environments are adopting more and more aspects of automation to enhance the services in hospitals. In pandemic conditions such as COVID 19, direct contact with patients may result in the spreading of disease. Hence the health community finds difficulty in distributing medicines and disposal of waste. The design and development of an automatic guided vehicle for hospital applications, which can be controlled remotely is specified here. AGV is a line follower robot, powered by a battery that can be charged from solar energy.

Shihua Li, Jing Yan, Lingxi Li, [4] *"Automated Guided Vehicle: the Direction of Intelligent Logistics"*, 2018.
Intelligent Logistics is one of the most important strategic directions for the development of modern logistics industry. Automated guided vehicle (AGV) is the key equipment the benchmark for the development of Intelligent Logistics. This paper analyzes the development history of AGV and their current application status, both at home and abroad. It also points out AGV's new direction for the development and advancement of China's Intelligent Logistics where we should focus on the research and promotion of AGV since they are artificial intelligence-oriented and based on the needs of Intelligent Logistics.

Lothar Schulze, Alexander Wullner, [5] *"The Approach of Automated Guided Vehicle Systems"*, 2011.
The automation of transportation in the production, trade and service sector is a key point in the optimization of intralogistics. Main points of these systems are the centrally controlled Automated Guided Vehicles (AGV). In the beginning, the vehicles were guided by optical or inductive guidelines. The main disadvantages of guidelines are the inflexibility concerning the modification and changing of the routing and the necessity of installations on or in the ground. New developments result in systems without guidelines. An example of this development is the laser guidance for the AGV. The AGVs have a high individuality. They are usually developed and constructed for the demands of a special application and are therefore unique.

Suman Kumar Das, M.K. Pasan, [3] *"Design and Methodology of Automated Guided Vehicle"*,2016.
There are several possible directions for further research. We can improved the guided tape type AGV utilizing better navigation technique. It can be adopted any environment and cheap among autonomous robot. There is significant amount of difference between theoretical and practical work cycle value of time which can be optimised by adopting different methodology. In addition, one could think of a relaxation of the token-holding requirement in the traffic control scheme so that multiple vehicles can leave different at-crossing zones simultaneously, and hence the performance of the AGV system can be improved.

3. Proposed System

3.1 Hardware Setup:

- Mount the NEMA 17 stepper motor on the AGV chassis to drive its movement.
- Connect the stepper motor to the A4988 driver module to control its rotation.
- Install IR sensors and ultrasonic sensors on the AGV to detect obstacles and navigate.
- Connect these sensors to the CNC shield or microcontroller (e.g., Arduino) for processing.
- Integrate a Bluetooth module for wireless communication with a remote control or central control system.

3.2 Software Development:

- Write an algorithm and code for the microcontroller (e.g., Arduino) to control the AGV's behaviour.
- Implement code to interface with the stepper motor through the A4988 driver module, controlling its speed and direction based on navigation commands.
- Develop algorithms to process data from IR sensors and ultrasonic sensors to detect obstacles and adjust the AGV's path accordingly.
- Integrate Bluetooth communication protocols to receive commands or transmit data wirelessly between the AGV and external devices.

3.3 Design

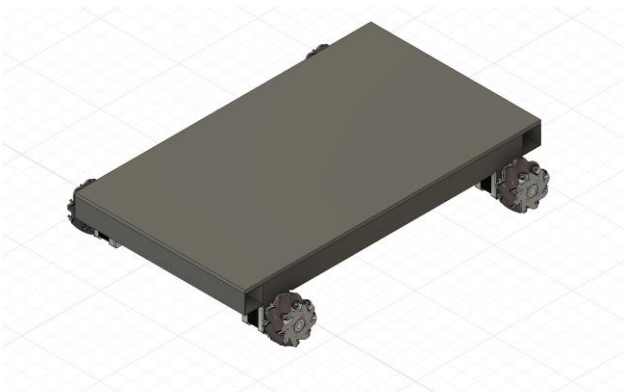

Fig-2 : Design of AGV in Fusion 360

3.4 Calculations

3.4.1 Material = C 45 (mild steel)

Take fos=2

σt = σb = 540/fos = 270 N/mm2

σs = 0.5 σt

= 0.5 x 270

= 135 N/mm2

3.4.2 Motor Calculation

Power of motor = 12
watt Rpm of motor = 500
rpm

Calculation For Final Speed & Torque

P=2πNT/60

12=2πx500xT/60 T = 0.229 N-m

T = 229 N-mm

3.4.3 Calculation of frame

Let the total weight (P) of our machine be 16 kg, now this 16 kg weight is kept on four angles,

P = 16 kg.

P = 16 x 9.8 = 156.8

N L = 480 mm

M = WL/4 = 16× 480/4

= 1920 N-mm

3.5 Proposed Modal fabrication

First, Choose lightweight and durable materials for the chassis. After that, Install four mecanum wheels on the chassis to enable omnidirectional movement. Attach stepper motors to each mecanum wheel to provide independent control. Conduct initial tests to calibrate the mecanum wheel kinematics for accurate motion control.

Mount line following sensors on the front or bottom of the AGV to detect lines or paths. Connect the sensors to a microcontroller for data processing. Develop algorithms to interpret sensor data and adjust the AGV's movement to follow the line accurately.

Connect the Bluetooth module to the microcontroller to enable wireless control and communication.

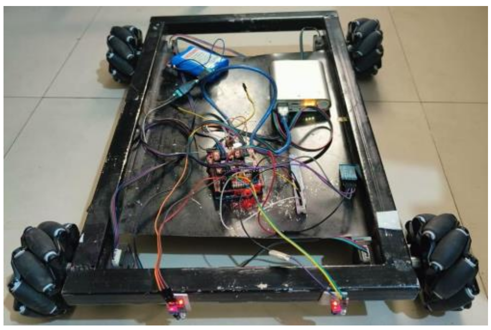

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Fig-3: Fabrication of AGV

3.6 Four 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. Due to the dynamics of these wheel, it can create force vectors in both the x and ydirection 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.

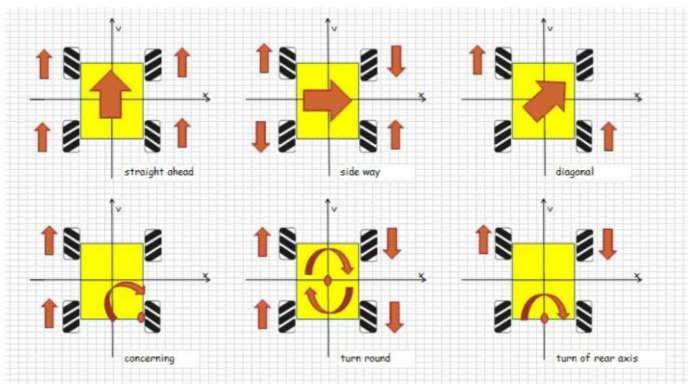

Fig-4: Net forces formed on Mecanum Wheels

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-5: Omni-Directional Results

4. CONCLUSIONS, FUTURE MODIFICATION & COST ESTIMATION

4.1 Conclusion

By integrating CNC shields, Nema 17 stepper motors, and A4988 driver modules, we achieve precise control and movement of the AGV, enabling smooth navigation and accurate positioning within the workspace. The stepper motors provide high torque and resolution, ensuring reliable performance in various operating conditions.

The inclusion of IR sensors enhances the AGV's ability to detect obstacles and navigate through dynamic environments safely. These sensors offer proximity detection capabilities, allowing the AGV to react promptly to changes in its surroundings and avoid collisions.

Ultrasonic sensors further augment the AGV's perception capabilities by providing distance measurement and obstacle detection in a wider range. This enables the AGV to navigate with greater awareness of its environment, including detecting objects at varying distances and heights.

4.2 Future Modification

Lifting Mechanism: The addition of a scissor lift table aims to enhance the AGV's utility by enabling it to lift and transport objects to different heights, facilitating tasks such as loading/unloading and assembly operations. The scissor lift mechanism will be designed to fit seamlessly with the existing AGV chassis, ensuring compatibility and efficient operation. The lift table will be integrated with the existing control system, allowing users to control its movement either manually through the Bluetooth module or autonomously using the line-following system.

Development of Mobile Application with Multiple Control Modes: To provide users with a more intuitive and flexible control interface, a dedicated mobile application will be developed to control the AGV in various modes. Bluetooth control mode will enable users to control the AGV's movement manually using the Bluetooth module, allowing for direct command inputs for navigation and operation. In line following mode, the AGV will autonomously follow predefined paths using the line-following sensors, providing hands-free operation for specific tasks or routes.

4.3 Cost Estimation

Sr. No.	Components	Cost / piece	Quantity	Cost
1	Microcontroller(Arduino board)	1650	1	1650
2	Motor driver module(A4988)	225	4	900
3	Stepper motor	650	4	2600
4	IR sensor	35	2	70
5	Ultrasonic sensor	100	1	100
6	Omnidirectional wheels	651	4	2604
7	Battery	650	1	650
8	Jumper wires	10	6	60
9	Breadboard	120	1	120
10	Resistor	10	1	10
11	Capacitors	25	1	25
12	CNC shield	113	1	113
	TOTAL			**8902**

Fig -6: Cost Estimation

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