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Design and Development of Low-Cost Automated Guided Vehicle

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Abstract: This research paper presents the design and manufacturing of a low-cost Automated Guided Vehicle (AGV) for material transportation, targeting small and medium-sized enterprises. The objective is to develop an affordable AGV using cost-effective materials and components, including mild steel for the chassis and Arduino for the control system. Different drive mechanisms, such as differential drive, omnidirectional drive, or meconium drive, are explored to achieve efficient and precise movement. The integration of the chosen drive mechanism with the control system ensures smooth navigation. The experimental work includes materials selection, CAD drawing, cutting, welding, drilling, finishing, and integration of components. The AGV prototype undergoes comprehensive testing and evaluation, considering factors like payload capacity, maneuverability, and obstacle detection. The research aims to provide a comprehensive solution for smaller businesses to enhance material transportation processes and improve operational efficiency.

Keywords: Automated Guided Vehicle, low-cost, material transportation, affordability, drive mechanism, operational efficiency.

I. INTRODUCTION

Automated guided vehicles (AGVs) play a crucial role in flexible production systems and are integral to the realization of modern logistics systems in line with Industry 4.0 requirements. Since their inception in the mid-20th century, AGVs have been employed to delegate monotonous tasks of product transportation from human workers to automated devices. Over time, the utilization of AGVs has yielded significant benefits for manufacturing companies. However, the high costs associated with purchasing and installing these devices pose a challenge, particularly for small and medium-sized enterprises seeking to adopt this technology on their shop floors (Johnson, 2018).

AGVs find applications in various industries and are often deployed for the transportation of diverse raw materials such as metal, plastic, rubber, or paper. For instance, they facilitate the movement of raw materials from receiving areas to warehouses or directly to production lines. AGVs ensure a consistent and reliable supply of raw materials without the need for human intervention, thereby ensuring uninterrupted production processes by guaranteeing the availability of necessary materials (Smith et al., 2020).

In addition to their role in material transportation, AGVs are extensively employed in work-in-process applications and the handling of finished goods, effectively supporting production or manufacturing lines. The term "work-in-process" describes products that are only half finished and quickly change from raw materials to final goods. AGVs enable the movement of materials or parts from warehouses to production lines or between workstations, thereby facilitating efficient and repetitive material flow throughout the manufacturing process. Without AGVs, production processes may be halted when processing lines experience material shortages, leading to delays as human workers retrieve necessary materials from storage and transport them to the production line (Brown, 2019).

AGVs also play a critical role in inbound and outbound handling tasks, including replenishment and picking operations. For example, they can be utilized to transport inventory from receiving areas to storage locations or from long-term storage facilities to forward picking locations for stock replenishment. By ensuring the availability of sufficient inventory at forward picking locations, AGVs enhance the efficiency of the order picking process. Collaborative mobile robots, categorized as AGVs, assist warehouse associates by guiding them through tasks and transporting picked orders to packaging and shipping workstations (Jones et al., 2021).

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The objective of this thesis work is to design and develop an AGV device that can be offered at a significantly lower price without compromising on flexibility and functionality. The focus is to cater to the needs of smaller businesses by incorporating affordable components that can effectively reduce the overall cost of the final product (Smith et al., 2022).

II. PROBLEM STATEMENT

The aim of this project is to design a low-cost Automated Guided Vehicle (AGV) capable of carrying a payload of 5 kg. The AGV should be equipped with the necessary sensors, control systems, and navigational capabilities to autonomously transport the payload within a specified environment. The primary objective is to develop a cost-effective solution that can be easily adopted by small and medium-sized enterprises, enabling them to automate material transportation processes and improve operational efficiency. The design should prioritize affordability without compromising on reliability, flexibility, and safety. Additionally, the AGV should be capable of seamlessly integrating into existing production or logistics systems, providing a user-friendly interface for programming routes and interacting with the vehicle's functionalities.

III. OBJECTIVE

The main objective of this project is to design and manufacture an Automated Guided Vehicle (AGV) using cost-effective materials, parts, technology, and driving mechanisms. The AGV will be constructed primarily using mild steel for the chassis, ensuring a balance between durability and affordability. The control system for the AGV will be developed using Arduino or Raspberry Pi, leveraging their versatility, accessibility, and cost-effectiveness.

In addition to the choice of materials and control system, the project aims to explore various drive mechanisms for the AGV. Different drive mechanisms such as differential drive, omnidirectional drive, or meconium drive will be considered and evaluated for their suitability in achieving efficient and precise movement of the AGV. The objective is to identify the most suitable drive mechanism that can meet the requirements of the AGV, including payload capacity, maneuverability, and cost-effectiveness.

Furthermore, the project will focus on ensuring the seamless integration of the chosen drive mechanism with the control system, allowing for smooth and accurate navigation of the AGV. The design and manufacturing process will also consider the ease of maintenance and repair, ensuring that the AGV can be easily serviced and upgraded in the future.
By achieving these objectives, the project aims to provide a comprehensive solution for designing a low-cost AGV using affordable materials, utilizing Arduino or Raspberry Pi for the control system, and exploring different drive mechanisms. This will enable smaller businesses to adopt AGV technology and enhance their material transportation processes, ultimately improving operational efficiency and competitiveness.

IV. EXPERIMENTAL WORK & PROCESS

The experimental work for the design and manufacturing of the low-cost Automated Guided Vehicle (AGV) involved several steps and processes. The following section provides an overview of the experimental work conducted.

A. Materials Selection:

The materials chosen for the AGV construction included MS sheet metal, plastic wheels, a DC motor, a lead acid battery, and an Arduino Uno R3 board. MS sheet metal was selected for the frame due to its strength and ability to withstand various loads. Plastic wheels were chosen for their lightweight and durability. The DC motor was utilized for the propulsion of the AGV, while the lead acid battery provided the necessary power supply. The Arduino Uno R3 board, equipped with an ATmega328 microcontroller, was used for control and programming purposes. Additionally, infrared, and ultrasonic sensors were incorporated into the design to enable obstacle detection and avoidance.

B. CAD Drawing:

A detailed CAD (Computer-Aided Design) drawing was created to visualize the AGV design and its components. The CAD drawing served as a blueprint for the construction process, providing precise measurements and dimensions for each part.

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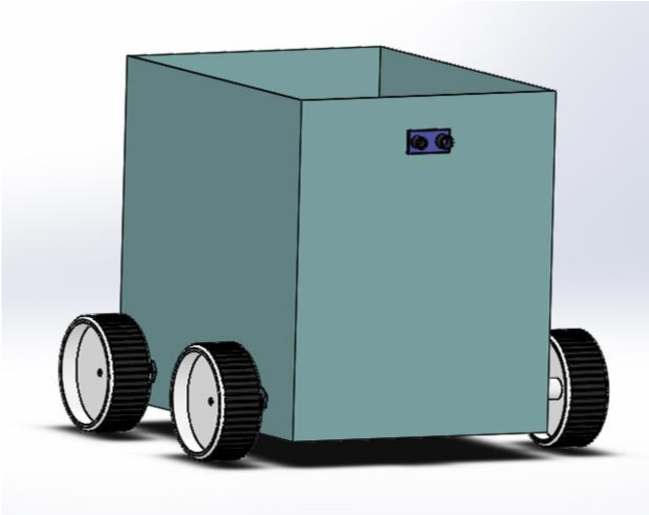
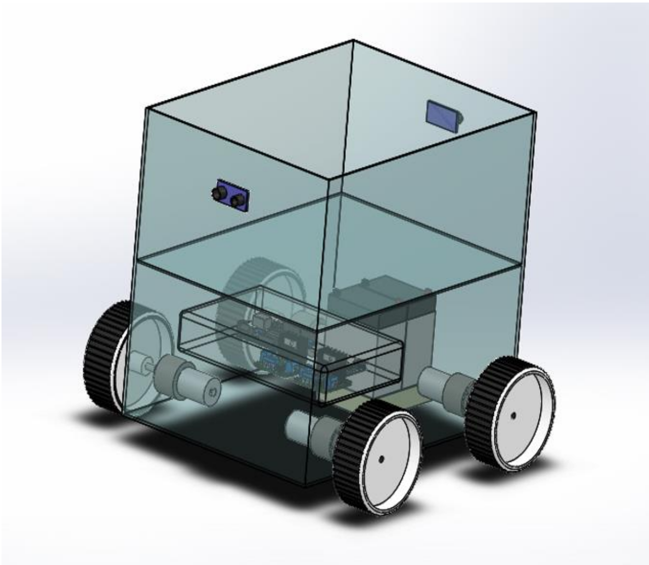
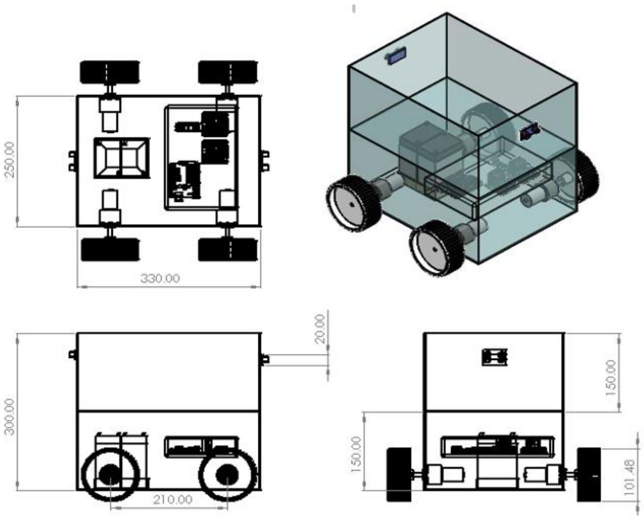


Front View



Isometric View



Drafting

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C. Cutting, Welding, and Drilling:

The MS sheet metal was cut and shaped according to the CAD drawing specifications. Various cutting tools and equipment were employed to achieve the desired shapes and sizes. Welding techniques were utilized to join the different parts of the frame securely. Additionally, drilling was performed to create holes for attaching components and assembling the AGV.

D. Finishing and Polishing:

After the assembly was complete, the AGV underwent finishing and polishing processes to enhance its appearance and smooth out any rough edges. Finishing techniques, such as sanding and painting, were employed to provide a clean and professional look to the AGV. Spray paint was used to add a protective layer and improve its aesthetic appeal.

E. Integration of Components:

The DC motor, Arduino Uno R3 board, infrared sensors, ultrasonic sensors, and battery were integrated into the AGV as per the design specifications. Wiring connections were made to ensure proper functioning and control of the AGV.

F. Testing and Evaluation:

Once the construction and integration of components were completed, the AGV underwent comprehensive testing and evaluation. The functionality of the DC motor, sensors, and Arduino board was verified to ensure proper operation. The AGV was tested for its payload capacity, maneuverability, obstacle detection, and overall performance.

Throughout the experimental work, meticulous attention was given to safety measures and quality control. Protocols were followed to ensure the proper functioning and reliability of the AGV. Any necessary adjustments or modifications were made to address any issues identified during the testing phase.

The experimental work undertaken in the design and manufacturing of the low-cost AGV involved cutting, welding, drilling, finishing, and polishing processes. These steps, along with the integration of the chosen materials and components, resulted in the development of a functional AGV prototype ready for further refinement and optimization.

G. Calculations:

Mechanical Properties of EN C45 steel:

Grade	Condition	Yield Strength R°(Mpa)	Tensile Strength Rm (Mpa)	Elon-gation A5(%)	Hardness HRC	Quenching Temperature (°C)	Benda-ability	Nominal Thickness,t 1.95mm≤t≤10.0mm	
								Rolled	Annealed
C45	Rolled Annealed Water-quenched Oil quenched	460 330	750 540 2270 1980	18 30	58 55	820 860	Min.reco-mmended Bending radius (≤90°)	2.0 ×t	1.0×t

Why Mild Steel C-45 was selected in our project.

i. Easily available in all sections.
ii. Welding ability.
iii. Machinability.
iv. Cutting ability.
v. Cheapest than all other metals.

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Material = C 45 (mild steel)

Take factor of safety 2

$\sigma t = \sigma b = 540/ \text{FOS} = 270 \text{ N/mm}^2$

$\sigma s = 0.5\ \sigma t$

= 0.5 x 270

$= 135 \text{ N/mm}^2$

Design Of DC Motor

Power of motor = 10 N- m /s

Rpm of motor = 30 rpm

CALCULATION FO FINAL SPEED & TORQUE OF MOTOR

Power of motor = P = 10 watt.

$$P = 2\pi\ N\ T / 60$$

Where, N→ Rpm of motor = 30

T →Torque transmitted

$10 = 2\pi \times 30 \times T / 60$
T = 3.182696317 N-m
T = 3182.696 N-mm

$$T = \text{Force} \times \text{radius } 3$$

$$3182 = F \times 50$$

$$F = 63.64 \text{ N}$$

$$F = 63.64 / 9.81$$

$$\mathbf{F = 6.4\ Kg}$$

This the force generated by individual motor; total force generated will be 25.6 kg.

V. COSTING

TOTAL COST	**AMOUNT**
RAW MATERIAL & STANDARD MATERIAL	6900
DIRECT LABOUR COST (Welding, Cutting, etc.)	3050
INDIRECT COST (Transportation, etc.)	2100
Total cost of project	**12050**

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VI. RESULTS AND DISCUSSION

The low-cost Automated Guided Vehicle (AGV) project was successfully completed with the design, fabrication, and integration of various components. The results obtained from the project, including the cost analysis and project flow, are discussed below.

Cost Analysis: The cost analysis involved evaluating the expenses incurred in procuring raw materials, standard parts, direct labor, and indirect costs. The total raw material cost amounted to 6,900 units, which included plastic wheels, MS sheet metal, Arduino microcontroller, spray paint, nuts, bolts, ultrasonic sensor, DC motors, IR sensor, batteries, charger, wires, Bluetooth module, and miscellaneous items. The standard parts cost totaled 3,050 units, encompassing turning, drilling, welding, grinding, cutting, assembly, and painting operations. The indirect costs, including transportation, coolant and lubricant, and project report, amounted to 2,100 units. Hence, the total cost of the project was determined as 12,050 units.

Project Flow: The project flow chart provided a systematic overview of the project's progression. It began with defining the objective, which was to design and fabricate a low-cost AGV. Extensive research was conducted on folding tables, stages, and suitable materials through various sources such as the internet and books. The design review stage ensured that all necessary considerations were addressed. Following the design review, the design process commenced, incorporating the acquired knowledge and lessons. Several design sketches were created, and the Pugh's concept selection method was utilized to choose the most suitable design. Solid modeling and engineering drawings were developed using software like SolidWorks.

The fabrication process involved various manufacturing processes such as welding, drilling, bending, and cutting. Fabrication errors were addressed promptly, and modifications were made as needed to ensure a smooth progress towards the final product. The draft report was then submitted to the supervisor for review and verification of any potential errors.
Discussion: The completion of the low-cost AGV project demonstrated successful implementation and integration of various components. The cost analysis provided insights into the expenses involved in the project, including material procurement, direct labor, and indirect costs. It highlighted the importance of proper planning and cost management to ensure the project's affordability.

The project flow chart illustrated a systematic approach to accomplish the project objectives. The initial research phase and design considerations played a crucial role in achieving a suitable and functional design. The utilization of CAD software facilitated precise modeling and engineering drawings, aiding in the fabrication process.

Throughout the project, adherence to quality control measures and attention to detail were paramount. Regular checks and modifications helped to address any errors or inconsistencies, ensuring a smooth progression towards the final product.

The successful completion of the low-cost AGV project opens up possibilities for various applications, such as material handling, warehouse automation, and transportation. Further refinements and optimizations can be implemented to enhance its performance, reliability, and functionality.

Overall, the results obtained from the project demonstrate the feasibility of developing a low-cost AGV with the chosen materials and components. The project serves as a foundation for future advancements and research in the field of automated guided vehicles, contributing to the evolution of robotics and automation in various industries.

VII. FUTURE SCOPE

The future scope of this research lies in several areas. Firstly, there is a need to develop more efficient thermoelectric generators (TEGs) by exploring new materials that can generate higher voltages and improve the conversion rate of heat into electricity. Additionally, optimizing the use of phase change materials (PCMs) in waste heat recovery systems can further enhance their efficiency. Integration of waste heat recovery technologies with renewable energy systems, such as solar panels or wind turbines, holds potential for increased energy efficiency. Industrial applications, including steel mills, cement plants, and chemical factories, can benefit from waste heat recovery systems, and research should focus on tailoring these technologies to specific industry needs. Furthermore, it is essential to assess the economic feasibility of TEGs and PCMs, taking into account factors such as initial investment costs, maintenance expenses, and potential energy savings.

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VIII. CONCLUSION

In conclusion, this research paper has focused on the design and development of a delivery robot equipped with sensors and a programmed system to ensure error-free operation and efficient document transportation. Through the utilization of Robot Operating System software and careful sensor selection, the delivery robot has been successfully designed and implemented.

The primary objective of this project was to create a delivery robot that could navigate autonomously, avoid obstacles, and transport documents with minimal human intervention. By incorporating the appropriate sensors and programming, the robot has demonstrated the ability to operate without errors, effectively avoiding barriers, and reaching its destination.

The utilization of Robot Operating System software has been instrumental in controlling and coordinating the robot's movements and actions. This software platform has provided a robust framework for developing and implementing the necessary algorithms and functionalities required for autonomous navigation and document transportation.

With the successful implementation of the delivery robot, several advantages have been realized. Firstly, the robot offers increased precision and accuracy in document transport, minimizing the potential for errors or damage. Additionally, the robot reduces the need for human involvement in the delivery process, resulting in enhanced efficiency and reduced time consumption.

By integrating obstacle avoidance sensors, the delivery robot can navigate through its environment while avoiding potential collisions. This feature ensures the safety of the robot and the documents it carries, mitigating the risk of accidents or damage during transit.

Overall, this research paper has presented a comprehensive approach to the design and implementation of a delivery robot. The utilization of sensors, programming, and Robot Operating System software has enabled the robot to function autonomously, providing efficient and error-free document transportation.

However, it is important to note that there is still room for further improvement and refinement. Future research and development could focus on enhancing the robot's capabilities, such as increasing its payload capacity, optimizing its navigation algorithms, or integrating additional sensors for more comprehensive environment perception.

The successful completion of this project showcases the potential of automation and robotics in streamlining document transportation processes. The delivery robot's ability to operate with minimal human intervention, increased precision, and reduced time consumption opens possibilities for its application in various industries, including logistics, offices, and other document-intensive environments.

In conclusion, this research paper contributes to the field of robotics and automation by demonstrating the feasibility and advantages of a delivery robot for document transportation. The outcomes of this project serve as a foundation for further advancements and research in the field, paving the way for more efficient and intelligent robotic systems in the future.

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