Auto-Guided Smart Forklift

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***Abstract*— Combination of automation and cognitive ability offers a creative way to change conventional warehouse and logistics processes through the concept of Auto guided smart forklift. The project focused on developing a prototype of a forklift capable of autonomous navigation, obstacle recognition, and adaptive decision-making by using modern technologies and sophisticated sensor systems. The initiative aims to increase operational effectiveness, eliminate human error, and promote workplace safety by automating routine materials handling operations. The project highlights the value of multidisciplinary cooperation in promoting innovation in industrial automation while also showcasing the potential of modern engineering. Through the establishment of new criteria for effectiveness, security, and productivity in warehouse and logistics management, the outcomes of this project have the potential to significantly impact the materials handling environment.**

Keywords*— Autonomous navigation, Obstacle recognition, Automation, adaptive decision-making.

I. INTRODUCTION

Material handling is a major activity supporting the manufacturing process in the industrial sector. Material handling refers to transferring raw materials and finished products from one place to another. Many techniques are used for material handling in the industry, such as conveyors, carton flow systems, and cranes.

A forklift is one of the most used methods. Traditional forklifts have been used for a very long time as essential workhorses in manufacturing facilities, distribution centers, and warehouses all over the world. The industry is being transformed rapidly from traditional methods to modern techniques with the help of emerging technologies. So, a firm needs to get modernized to survive and compete in its industry. Otherwise, it couldn't be stable and ensure its existence in the field.

Material handling is not such a complex process; it is simple and repetitive. So, there is no need for a man to compulsorily exist there. So, this procedure may be automated using the line-following approach, and also some other extra smart features can be added to the system for ease of the process.

This method makes the process easier and reduces costs by removing the workforce needed for material handling. The well-trained auto-guided forklift will not make errors and will function with precision. Accidents due to carelessness and critical situations can be avoided. Machines are more reliable than workers, so auto-guided smart forklifts will be the better option.

The reliance on human operators for the material handling process creates issues with accuracy, productivity, and safety. Forklifts are manually driven by workers in the factory for a long period. A large number of man-hours are being wasted due to this. A labor needs a specific amount of training and a trial running period to get expertized with forklift driving.

In the administration's view, these could be concerned as a waste of time and money. A forklift driver's carelessness may cause accidents inside the factory. The damages and critical situations created due to this may affect the production flow and waste time inside a manufacturing unit. Always an automated process using a machine is more accurate and precise than a manual process operated by a human.

The primary objective of the project is to automate the material handling process and other objectives as follows - maintain a real-time inventory for transferred finished goods and raw materials, avoid accidents and damages due to incautiousness of labor, and reduce the cost of manufacturing.

II. RELATED WORK

A. Path following hybrid control for vehicle stability applied to industrial forklifts.

A closed-loop hybrid controller for route following with industrial forklifts moving large loads at fast speeds is shown in the paper. During route following, the controller strives to maintain the vehicle's stability, safety, comfort, and slippage. Double Continuous Curvature (DCC) routes, which serve as the foundation for path tracking, are introduced as a kind of continuous curvature path generated by a kinematic controller. A safe and pleasant driving experience is promoted by the kinematic controller, which creates speed and curvature profiles for the forklift. The article's closed-loop hybrid controller, which blends kinematic and dynamic components for better route-following performance, is its key contribution. [1]

B. Digital twin for automated guided vehicles fleet management

In the context of Industry 4.0, the offered research paper explores the need of modifying conventional Automated Guided Vehicle (AGV) management systems to include Digital Twins capabilities. In the age of digital transformation, the study emphasizes the growing integration of software systems with goods for remote administration. The systems used to handle AGVs also don't have the functionality needed for Industry 4.0. The advantages of upgrading AGV management systems to use Digital Twins are examined in the proposal by Matei Alexandrua, Circa Dragoșa, and Zamfirescu Bălă-Constantina. [2]

C. Development of an obstacle-avoiding autonomous vehicle by using stereo depth estimation and artificial intelligence-based semantic segmentation

The article "Development of an Obstacle Avoiding Autonomous Vehicle by Using Stereo Depth Estimation and Artificial Intelligence Based Semantic Segmentation" is concerned with the creation of an autonomous vehicle that can avoid obstacles using stereo imaging systems and artificial intelligence methods. The goal of the work is to design a vehicle that can accurately avoid obstacles while drawing semantic inferences about its surroundings. The importance of computer vision in mimicking human comprehension and decision-making processes is emphasized in the paper. It emphasizes the use of depth data for several uses, including autonomous driving, navigation, and distance estimate. There is a short discussion of several sensing technologies, such as LiDAR, radar, ultrasonic sensors, and stereo cameras. The research places special emphasis on passive sensing techniques like stereo cameras that record depth information via image processing. [3]

D. Efficient calibration of four-wheel industrial AGVs

[4] A unique approach for the automated calibration of four-wheel industrial Automated Guided Vehicles (AGVs) using Ackermann and Dual Drive kinematics is introduced in the literature study. AGVs are essential for logistics transit within industrial facilities and need to be precisely positioned and navigated. AGV calibration includes extrinsic parameters that specify the location of the sensor on the robot for localization as well as intrinsic parameters that link wheel instructions to motion. Manual calibration takes time and is uneven across AGVs. The research presents a novel calibration approach for four-wheel AGVs that takes into account both intrinsic and extrinsic factors. The technique provides a more precise and effective substitute for manual calibration, enhancing AGV placement and navigation in industrial settings. [4]

E. Management and Transport Automation in Warehouses Based on Auto-guided Vehicles.

AGVs are used in the article's entire management and transportation automation solution for warehouses. Within warehouses, management automation and transport automation are the main topics of the research project Auto Trans. The research project Auto Trans, which combines optimum location management, RFID-based identification, transport automation, teleoperation, and SCADA oversight, offers an integrated solution for warehouse management and automation was published by Marta C. Mora, Leopoldo Armesto, and Josep Tornero. [5]

III. METHODOLOGY

3D model of is designed for better understanding of structure and functions of forklift. Then the autonomous navigation of forklift is performed. Forklift mechanism to lift and place the pallets is acquired then data collected from force sensor and stored in database.

A. 3D Modeling

3D modeling is very essential for any products that are manufactured, Solid Edge CAD software have been used to design forklift. 3D model of forklift will give a better idea and calculations of force transfers and load balances.
Also, creative ideas can be put on forklift design through the CAD modeling part and has precise dimensions for fabrication.

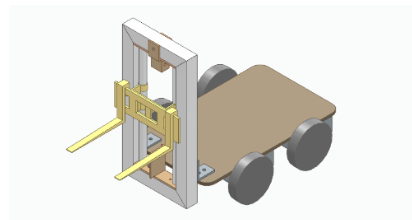

Fig. 1. CAD Model of Forklift

B. Fabrication and Assembly of parts

The chassis part for the forklift was made of wood and forklift frame made from square aluminum bars. The forklift frame was assembled by reverting. Also, two cylindrical aluminum tubes have been placed between the frame so the forks can travel top to bottom through them. The movable fork parts of the forklift like carriage, pulley was fabricated by 3D printing dur to complexity of design and needs more accuracy.

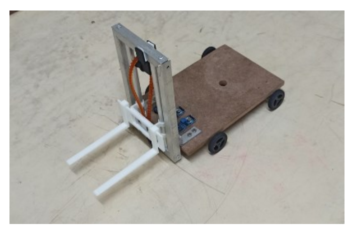

Fig. 2 Fabricated Forklift

C. Line following technique

The line following is the basic technique used for the motion of the forklift in this project. Three IR sensors, four Dc motors, L293D motor driver IC and ESP 32 microcontroller have been used to achieve autonomous navigation. Based on the input signal from the IR sensors, motors are operated and controlled through motor driver IC. The black color line for the path of forklift is drawn on the white floor. IR sensors are fixed in the front of the forklift, facing downwards the floor. Forklift moves along the path using the sensor readings, moving direction is controlled by varying the speed of the motors. The speed control of the motors will be done using enable pins of the motor driver using the PWM function. The motor driving the right-side wheel will be slowed and left speed up, to turn the vehicle right side. As well as for turning left side. The spinning direction of the motor can be controlled by applying HIGH (5V) or LOW (0V) logic values to the motor driver's inputs. [6] [7]

TABLE I. Direction control of DC motor

IN 1	IN 2	Spinning Direction
Low(0)	Low(0)	Motor OFF
High(1)	Low(0)	Forward
Low(0)	High(1)	Backward
High(1)	High(1)	Motor OFF

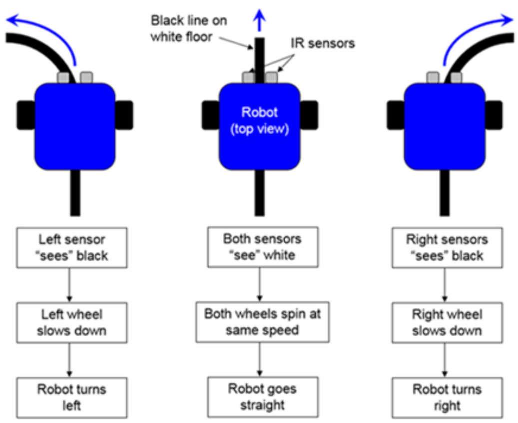

Fig. 3. Line following technique

D. Forklift mechanism

The forklift mechanism is achieved by a 28BYJ-48 Stepper Motor, ULN2003 Driver, Motor Drive V Belt, and Pulley. The forklift travels along the blackline and identifies the spot where the pallets are. Then the system actuates the stepper motor, the stepper motor starts rotating to the predefined angles. The forklift subassembly which carries the pallets is connected to the stepper motor using a V belt through the pulley. So, it goes up and the pallet is lifted to a defined height. Then the forklift travels and reaches the destination where the pallets need to be placed. Finally, the stepper motor rotates an equal number of angles in the opposite direction and the V belt gets loosened, and the pallet is placed down.

E. Pallet detection

Reed switch is used to identify the pallets with the help of magnetic field. A piece of magnet will be placed in the pallet and Reed switch in the forklift. When the forklift gets into magnetic field Reed switch gets actuated and gives signal. Then, stepper motor starts, and forklift mechanism works.[9]

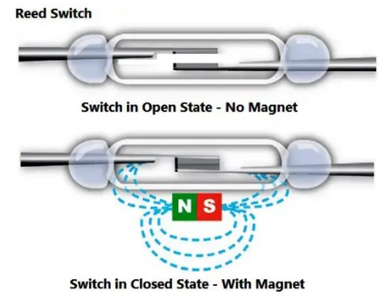

Fig. 4 Function of Reed Switch

F. Real time inventory maintenance

The forces created on forks due to carrying the pallets will be measured using force sensors fixed on the forks. The readings of force sensor sent to the database through Wi-Fi from the ESP32. Then the readings are processed, and number of products handled by forklift are gained, stored in database as an inventory.

$$\text{Mass of transferred Load} = \frac{\text{Force sensor reading} - \text{Pallet's weight}}{\text{Gravitational Acceleration (9.8m/s2)}}$$

$$\text{Quantity of transferred Products} = \frac{\text{Mass of total load transferred}}{\text{Mass of a product}}$$

IV. RESULTS AND DISCUSSION

Successful use of the line-following method with IR sensors has been displayed. The forklift was able to follow the given track due to the IR sensors successfully identifying the predefined lines on the floor. We created an algorithm that guaranteed reliable tracking and smooth motion. The approach we use gave the forklift the flexibility needed for moving through a restricted area by allowing it to adapt to both straight tracks and curved parts.

For pallet detection, the combination of Reed switch sensors with RFID technology produced accurate and on-time results. Pallets' RFID tags were quickly identified as they came into range of the forklift, enabling rapid modifications to the forklift's approach. The correct placement of the pallets during loading and unloading was confirmed by the Reed switch sensors, which provided additional information to the RFID data. The efficiency and safety of the material handling process were both increased by the use of these two technologies together.

Fig. 5. Line following movement of Forklift

Fig. 6. Pallet identification of Forklift

Fig. 7. Lifting up and down process of Forklift

The forklift mechanism, which was powered by a stepper motor through a V-belt and pulley set-up, demonstrated dependable and accurate control. The forklift was able to move in a regulated manner because of the stepper motor's step-by-step rotation and the V-belt and pulley system efficiently converted the motor's rotational action into linear motion. This set of elements produced steady lifting and lowering operations, which are essential for effective material handling.

The inventory system's integration of a force sensor gave crucial real-time input on the weight of loaded goods. This information was effortlessly sent to a Firebase real-time database, allowing for immediate inventory level monitoring. This system's integration gave the administration a thorough understanding of stock flow, enabling them to make proactive restocking choices. The force sensor and Firebase database worked together to increase operational transparency and lower the probability of stockouts. [6]

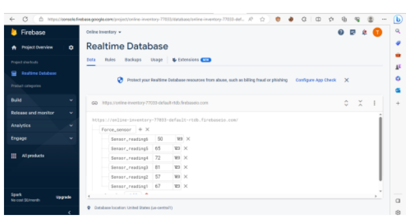

Fig. 8. Online inventory in Real time database

As a result, the auto-guided smart forklift project has achieved the successful fusion of several cutting-edge technologies to provide a complete answer for effective material handling. A unified and efficient automated system has been produced by combining line following, forklift mechanism, pallet detection, and inventory management technologies. We have developed a practical and dependable solution that improves productivity, accuracy, and safety in material handling operations via thorough design, integration, and testing.

V. CONCLUSION

The Auto-Guided Smart Forklift project's development and implementation process has been an example of creativity, collaboration, and technical improvement. By integrating automation and intelligence into forklift operations, this project aims to transform the materials handling sector and boost efficiency, security, and overall production. The designing and fabrication of the forklift, autonomous navigation of the forklift using line following technique, forklift mechanism with the help of stepper motor, pulleys, and V belt, pallet detection, and online based inventory system using Firebase were successfully completed and implemented. It functioned properly and achieved the objectives of the project. As we complete this project, there are a few important lessons learned and accomplishments that excellence appreciation.

In conclusion, the Auto-Guided Smart Forklift project has shown how automation, intelligence, and cooperation have the power to make things better. It has raised the standard for future similar endeavors and pushed beyond the limits of what is feasible in the materials handling sector. The project's success is a landmark to the amazing possibilities offered by modern engineering, and it predicts a future in which automation and human skill will work together to build workplaces that are safer, more effective, and more productive.

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