INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH AND ANALYSIS

ISSN(print): 2643-9840, ISSN(online): 2643-9875

Volume 07 Issue 12 December 2024

DOI: 10.47191/ijmra/v7-i12-11, Impact Factor: 8.22

Page No. 5450-5456

Design and Development of an Automated Forklift with IOT Weight System

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ABSTRACT: This paper presents the design and development of an automated forklift system with integrated IoT-based weight monitoring and RFID-based pallet identification, aimed at enhancing efficiency and safety in industrial material handling. The forklift autonomously identifies, loads, and transports pallets using RFID technology, ensuring accurate pallet selection and handling. The IOT- based weight system, monitored via the Blynk app, enables real-time load tracking and overload alerts, safe operation. Path-following capabilities are achieved using IR sensors, while ultrasonic sensors provide effective obstacle detection, allowing precise navigation within medium scale industrial environments. By minimizing human intervention, the forklift system optimizes productivity, and offers a scalable solution for medium- scale industries. Results demonstrate the forklift's effectiveness in automating complex tasks in industrial settings, contributing to improved workflow and operational reliability.

KEYWORDS: Autonomous forklift, IOT weight system, RFID technology, Line-following navigation, Obstacle detection, Industrial IOT Load monitoring, Medium-scale industries

I. INTRODUCTION

Forklifts are fundamental to various industrial operations, playing a key role in material handling across sectors such as warehousing, logistics, and manufacturing. Traditionally, these vehicles rely on human operators for maneuvering, load handling, and transport, making them susceptible to human error, inefficiency, and safety risks. With the rapid evolution of industrial automation, there is a growing need for autonomous solutions that can perform these tasks independently, enhancing both productivity and safety.

Recent advancements in automation and IOT (Internet of Things) technologies have paved the way for the development of autonomous forklifts, which can operate without human intervention. Autonomous forklifts equipped with IOT-enabled weight monitoring systems can accurately assess and transport loads, minimizing the risk of accidents due to overloading or improper handling. Integration of technologies such as RFID for pallet identification and line- following navigation enables precise and efficient movementwithin industrial environments, while obstacle detection sensors ensure safe navigation in dynamic spaces

This paper presents the design and implementation of an autonomous forklift system integrated with IOT-based weight monitoring. The system autonomously identifies, loads, and unloads pallets using RFID technology and monitors load weight in real-time through an IOT-enabled interface, enhancing safety and operational efficiency in industrial settings. By replacing manual operations with autonomous processes, the forklift system aims to address the challenges of material handling in medium-scale industries,

II. RELATED WORK

A. Problem Statement

1) Introduction

Robots play a crucial role in today's automated manufacturing systems, especially in hazardous environments where manual intervention is unsafe. The development of obstacle-avoidance robots presentssignificant opportunities for innovation, leading to a variety of mobile robots capable of performing multiple functions. Designing an Automated Guided Vehicle(AGV) is a complex task that involves both hardware and software challenges. The software must adapt to variable inputs, and the outputs need to be carefully selected to guide the design process. These factors are interdependent, meaning that hardware and software considerations must be addressed simultaneously rather than separately. The long-term objective is to fully automate the transportation of materials between trailers and production lines in automotive stamping and assembly plants. This includes tasks such as picking up and placing loads at variouslocations within medium-scale industries, including interaction with other AGVs, automated storage and retrieval systems, and staging areas near production lines. The design of the lifting machines should be efficient, user-friendly, and cost-effective, especially in terms of materialcosts.

B. AIM

To develop an autonomous forklift with IOT weight system using sensors to load and unload the materials for medium scale industries

C. Pallet Idenrification Using RFID

Pallet identification is achieved using RFID (Radio Frequency Identification) technology. Each pallet is equipped with an RFID tag containing unique identificationdata. When the forklift reaches the pallet location, the RFIDreader installed on the forklift scans the tag on the pallet This process enables the system to confirm the presence andidentity of the correct pallet before proceeding with loadingoperations. By ensuring that only the intended pallet is handled, RFID-based identification minimizes handling errors and enhances the efficiency and accuracy of materialmovement in the automated setup.

D. IOT Weight System Using Blynk App

Using the Blynk app, the weight data is transmitted over Wi-Fi, allowing remote monitoring and real-time data display ona smartphone. The Blynk app provides an intuitive interface where operators can view the weight of the load in real time, receive alerts if the weight exceeds the designated safety limit, and maintain records of the loads handled by the forklift. This IOT integration not only adds a layer of safety by preventing overloads but also improves operational efficiency, ensuring optimal load handling and distribution.

E. Efficient calibration of three wheel for medium scaleindustries

Efficient calibration of a three-wheel forklift is crucial formaintaining stability, accuracy, and safety during operation, especially in autonomous systems. The forklift, which features a single caster wheel and two wheels for support, requires precise calibration to ensure balanced load distribution and responsive maneuverability. The

steering wheel's turning radius must be accurately set to enable smooth navigation within tight industries aisles, while ensuring that the caster wheel aligns perfectly with the intended path. the rear wheels need calibration to prevent tipping risks during lifting and transport. By fine- tuning these elements, the forklift achieves optimal balanceand performance, which helps reduce wear on components,minimizes the risk of operational errors, and ensures consistent handling of loads.

F. Development of an Obstacle Avoidance

The sensor data is processed by the forklift's microcontroller, which continuously monitors the surrounding area for potential hazards. When an obstacle is detected within a predefined safety range, the control system take action to prevent a collision by stopping the forklift and re-routing around the obstacle if possible. This automated response allows the forklift to operate autonomously even in busy or cluttered spaces, significantly reducing the risk of accidents and enhancing workflow continuity.

G. Path Following

Path following is a critical function for autonomous forklifts, allowing them to navigate pre-defined routes within a warehouse or industrial setting accurately and efficiently. Inthis project, path following is achieved using line-following technology, where the forklift detects and follows a marked line on the floor using sensors, typically infrared (IR) sensors. These sensors continuously scan the floor, detectingthe contrast between the line and the surrounding floorsurface.

III. METHODOLOGY

A 3D model of the forklift was developed to provide a clearunderstanding of its structural design and operational functions. Following this, autonomous navigation capabilities were implemented to allow the forklift to move independently within its designated space. The lifting mechanism, essential for handling and positioning pallets, was configured and integrated. Additionally, data from the load cell sensor wascollected and systematically stored in a database for real-time monitoring and future analysis.

A. 3D Modelling

3D modeling is crucial across many industries because it allows for the creation, visualization, and precise manipulation of digital representations of objects, characters, and environments. This capability enhances realism and provides detailed views from multiple angles, 3D modeling enables the creation of prototypes and simulations, allowing for early testing and refinement that can identify potential design flaws. A better understanding and calculation of force transfers and load balances will be provided by using Solid Edge Cad software to create the forklift 3D model. the cad modeling portion will generate new ideas for forklift design and provide accurate measurements for fabrications.

B. Components Used

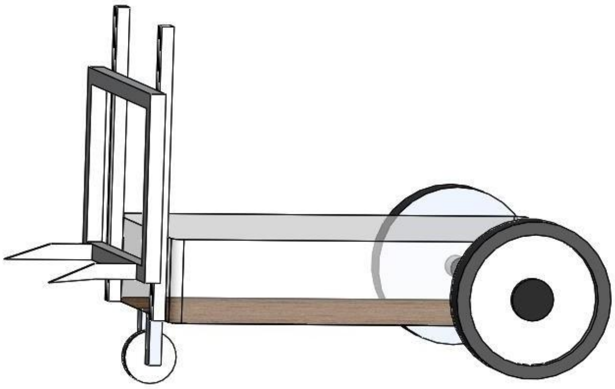


Figure 1 CAD Model of forklift

- IR sensor
- Arduino UNO
- Load cell with HX711 Module
- Ultrasonic sensor
- ESP32 Module
- RFID Module
- Geared motor
- LCD Display
- Motor Drivers
- 12V Battery

C. Fabrication and assembly of Parts

The fabrication and assembly of an autonomous forklift involve constructing its physical framework, integrating essential components, and ensuring proper functionality ofeach subsystem. The process begins with designing and fabricating the chassis, which must be robust enough to support the forklift's load capacity while being maneuverable within confined spaces. The structure andmaterials used in building a specific chassis and fork

system. The chassis is made of wood, which serves as the base of the body to which other components are attached. The fork, which is made of aluminum, is a crucial part thattypically holds the front wheel and allows for steering. Twocylindrical aluminum tubes are integrated between theframe sections. These tubes are aligned vertically, allowingthe fork to move or slide up and down through them.

Assembly begins with the installation of motors, typically geared motors, for driving and lifting. The motors aremounted onto the chassis along with motor drivers and connected to a power source, often a rechargeable battery system. Next, sensor modules, including ultrasonic sensorsfor obstacle detection and infrared sensors for path following, are positioned strategically around the forklift tomaximize coverage and accuracy. The load cell and RFID reader are mounted on or near the forks to support real-timeload measurement and pallet identification.

All electronic components, including the microcontroller (such as an Arduino), are wired and connected. The wiringincludes power distribution, signal connections from sensors to the microcontroller, and outputs to the motor drivers for controlling movement. An IOT module is integrated to connect the forklift to the Blynk app, allowing for remote monitoring and data visualization.

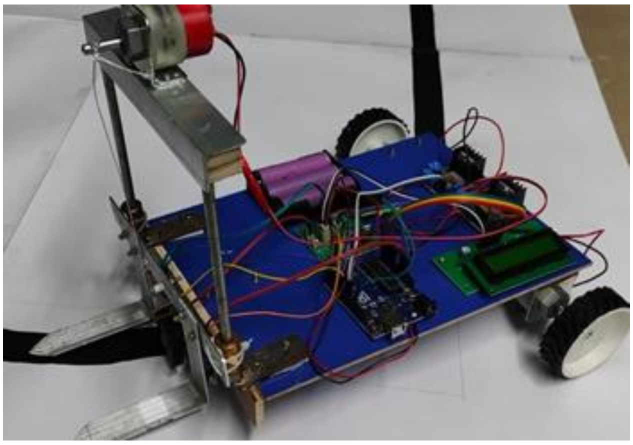


Figure 2 Fabrication and Assembly

D. Forklift Mechanism

. The forklift mechanism consists of a lifting system, drive system, and control system, working together to allowautonomous material handling. The lifting mechanism typically involves a set of forks attached to a vertical mast. The mast uses a geared motorized lifting system, which canbe electrically driven, to raise and lower the forks smoothly,allowing the forklift to pick up and place pallets at varyingheights.

The drive system usually consists of Front caster wheel forstability and two wheels that enabling the forklift tomaneuver in confined spaces. Geared motors control the movement, providing the necessary torque for forward, reverse, and turning operations. This setup allows precise movement control, critical for navigating within warehouseaisles and approaching pallets accurately

For movement, the forklift relies on two powered front wheels for forward and backward motion, with a single rearwheel providing steering. This three-wheel configuration ensures stability and maneuverability, especially in tight spaces typical of industrial environments. The control system integrates sensors, including IR for path following,RFID for pallet identification.

Figure 3 Fork with load cell

E. Line Following Concept

Line following is the fundamental technique for guiding theforklift along a specified path. To enable autonomous navigation, two IR sensors are mounted at the front of the forklift, facing downward toward the floor. These sensors detect a black line drawn on a white surface, which serves as the forklift’s designated path. When the IR sensors detectthe line, they send signals to the main controller of arduinouno microcontroller, which processes these inputs to determine the forklift’s position relative to the line.

The Arduino uno controls the forklift two DC motors through an L298 motor driver. Based on the sensor input, the motor driver adjusts the speed and direction of the motors to keep the forklift aligned with the path. If the forklift needs to turn right, the motor on the right side will slow down, while the left motor speeds up, creating a differential in speed that turns the vehicle. Similarly, for leftturns, the left motor slows while the right motor speeds up.the microcontroller can finely control motor speed, allowing smooth and precise adjustments to maintain accurate line-following.

The motor direction is managed by applying either a HIGH (5V) or LOW (0V) signal to the motor driver’s input pins, which determines the forward or reverse motion of each motor.

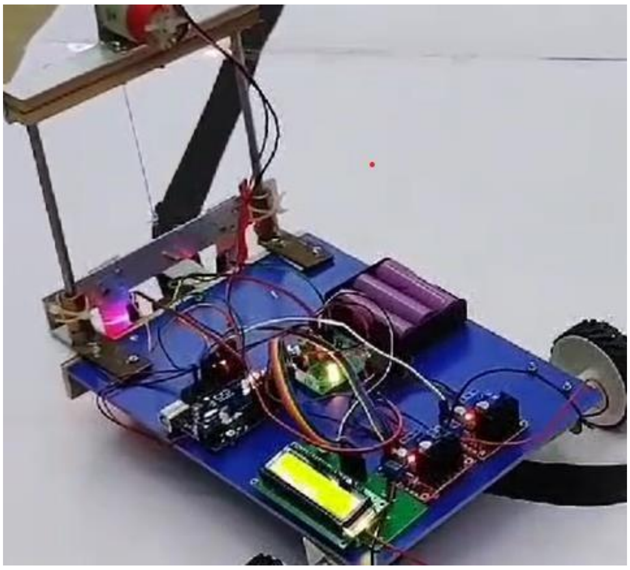


Figure 4 Line Following

When the forklift is centered on the line, the sensors pick up an even reflection pattern, indicating the correct path. However, if the forklift begins to deviate, the reflection pattern shifts as one or more sensors lose contact with the line. This change is processed by the forklift's controlsystem, which immediately adjusts the steering or wheels to bring the forklift back onto the line.

F. Pallet Identification

Pallet identification is achieved through the use of RFID (Radio Frequency Identification) technology. Each pallet isfitted with an RFID tag that holds a unique identifier. Whenthe autonomous forklift approaches a pallet, an RFID reader on the forklift emits a signal that activates the tag, prompting it to transmit its unique identification data back to the reader.

The control system on the forklift receives and processes this data to verify that the pallet matches the intended targetfor pickup or delivery. This identification process ensures that the forklift handles the correct pallet, reducing errors and improving operational accuracy. By integrating RFID- based pallet identification, the forklift can streamline its operations in busy environments, allowing it to automatically select, transport, and position pallets accurately and efficiently without manual intervention.

Each pallet is equipped with an RFID tag containing uniqueidentification data. When the forklift reaches the palletlocation, the RFID reader installed on the forklift scans thetag on the pallet. This process enables the system to confirmthe presence and identity of the correct pallet before proceeding with loading operations. By ensuring that only the intended pallet is handled, RFID-based identification minimizes handling errors and enhances the efficiency andaccuracy of material movement in the automated setup

G. IOT weight system

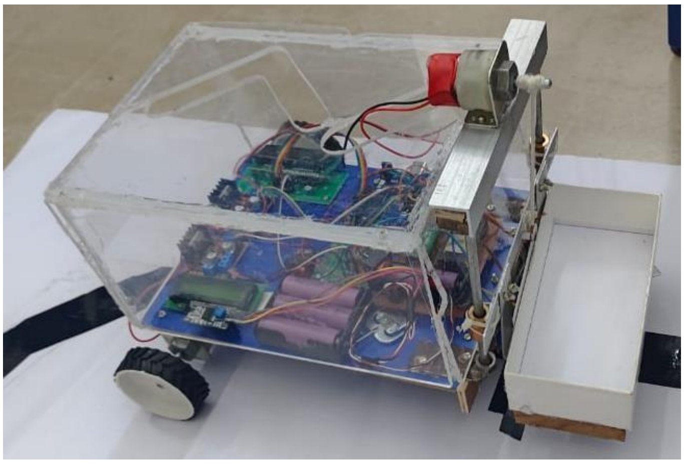
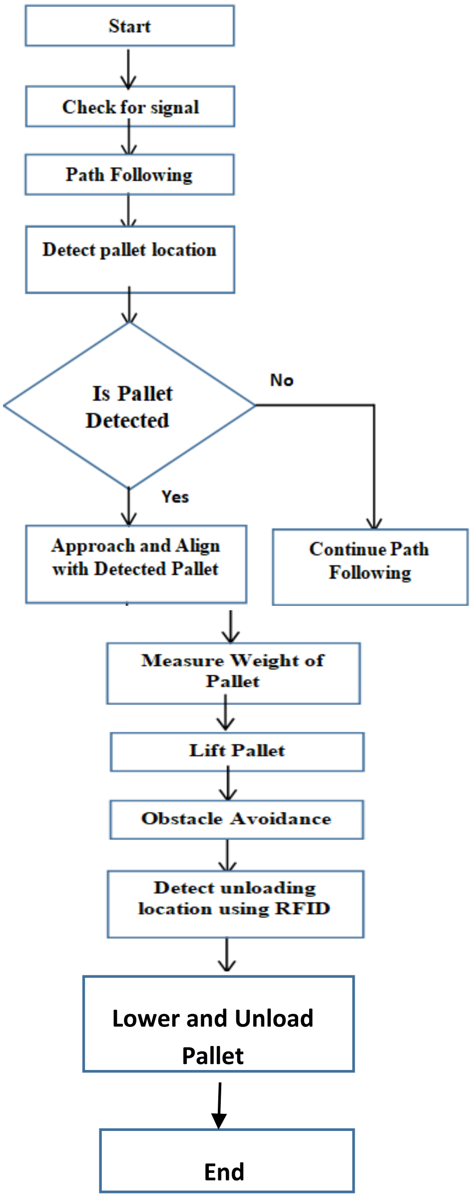


Figure 5 Pallet identification

The IOT weight system enables the autonomous forklift tomonitor and manage load weights in real-time, ensuring safe and efficient handling. The system is built around a load cell sensor, which is installed on the forklift's forks to measure the weight of each pallet being lifted. The load cell captures the weight data and sends it to an HX711 amplifier module, which converts the analog signal into adigital format that can be processed by a microcontroller ESP32.

The weight data is then transmitted via Wi-Fi to the Blynkapp, an IOT platform that displays real-time data on a connected smartphone or computer. Through the Blynk app, operators can monitor the weight of the load remotely, view alerts if the weight exceeds safe limits, and access historical data for tracking and analysis. This system improves safety by preventing overloads, and it enhances operational efficiency by providing immediate,actionable insights into load management. By integratingIOT capabilities with the weight system, the forklift offersa connected and user-friendly approach to load monitoring in industrial environments.

H. Working Flow Chart



IV. RESULT

The results of this project demonstrate the successful implementation and operation of the autonomous forklift system, achieving notable improvements in material handling efficiency and safety. The RFID-based pallet identification system enabled the forklift to accurately locate and handle specific pallets, significantly reducing errors in selection and transport. This capability enhances operational accuracy in busy environments, where precise pallet handling is critical. Additionally, the IOT-based weight monitoring system, integrated with the Blynk app, allowed for real-time load tracking and instant alerts for any overloads, ensuring compliance with safety standards and preventing damage to the forklift or goods.

The path-following mechanism, supported by IR sensors, enabled precise navigation along predefined routes, while ultrasonic sensors provided effective obstacle detection, ensuring smooth and safe movement even in confined medium industry. This autonomous operation minimized the need for manual intervention, allowing the forklift to independently carry out tasks like identifying, lifting, transporting, and unloading pallets

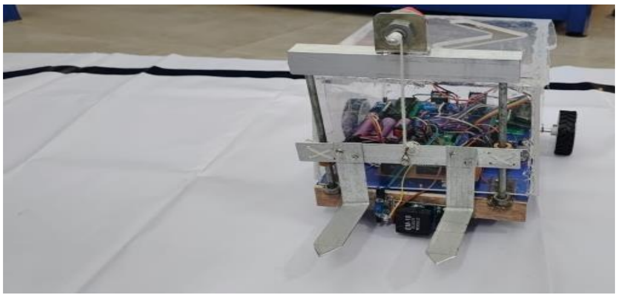


Figure 6 Fabrication

V. CONCLUSION

This project successfully developed and demonstrated an autonomous forklift system with integrated IOT and RFID capabilities, achieving significant advancements in automated material handling. The forklift's RFID-based pallet identification enabled accurate selection and handling of pallets, reducing operational errors and enhancing efficiency. The IOT-based weight monitoring system, combined with the Blynk app, allowed for real-time weight tracking and alerts, ensuring load safety and compliance with weight limits The line-following and obstacle detection mechanisms facilitated reliable navigation within constrained spaces, while minimizing collision risks. This autonomous functionality, including precise pallet handling, path following, and safe load management, reduced the need for human intervention, leading to improved productivity and reduced labor costs, particularly suited for medium-scaleindustrial applications. Overall, the autonomous forklift system offers a reliable, efficient, and safe solution for industrial automation, with the potential to streamline workflows, enhance safety for medium scale industries.

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