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Autonomous Industrial Load-Carrying Robot using STM32

Dr. Tabitha Janumala
Department of Electronics and Instrumentation Engineering
Assistant Professor
RV College of Engineering
Bengaluru, India

Pavan K L
Department of Electronics and Instrumentation Engineering
RV College of Engineering
Bengaluru, India
1RV24EI401

Mohammed Firasath Khan
Department of Electronics and Instrumentation Engineering
RV College of Engineering
Bengaluru, India
1RV24EC033

Keerthi U K
Department of Electronics and Instrumentation Engineering
RV College of Engineering
Bengaluru, India
1RV23EI025

Vedanth S
Department of Electrical and Electronics Engineering
RV College of Engineering
Bengaluru, India
1RV23EE059

***Abstract*—The development and designing of an autonomous industrial load carrier robot using STM32 microcontroller is discussed in this paper. This system will uses the ultrasonic sensors for detecting obstacles and human-following capability, along with an infrared sensor on the backside for shutting down the robot in case of danger. The robot has to the ability to follow the human operator, keep a safe distance from the operator, and carry out load transportation. Furthermore, use of an Wi-Fi control module based on ESP32 makes sure that the robot can be controlled manually if needed. The system was successfully designed and tested using an STM32 controller and L298N motor driver. It is expected that the developed system will help in reducing manual labor in both small and large-scale industries.**

***Index Terms*—STM32, Autonomous Robot, Human Following Robot, Obstacle Detection, Ultrasonic Sensor, Infrared Sensor, Load Carrying Robot, Industrial Automation, Wi-Fi Controlled Robot, ESP32, Embedded Systems**

I. INTRODUCTION

Manual handling of materials in contemporary industrial settings poses substantial difficulties for workers, leading to exhaustion, lowered efficiency, and a higher probability of sustaining bodily harm. Small- and medium-sized industries are especially reliant on human efforts to move why because they cant lift more weight sophisticated automated systems for moving things. Clearly, there exists a need for an intelligent system that helps humans transport loads without causing any problems.

Mobile robots have been recognized as a feasible alternative to automating the industrial setting. The Mobile robot system has been successfully developed with capabilities to navigate their environment and accomplish assigned jobs with minimum human interference. Unfortunately, many existing mobile robot systems are not affordable and/or do not have important safety considerations incorporated into them. Therefore, a need exists for an intelligent robotic system that combines navigation and safety.

In this research, an autonomous load carrying robot is designed using STM32 microcontroller. In the system, ultrasonic sensors have been incorporated in the system to detect any obstacles as well as human-following ability. Consequently, the robot will follow and help the human operator but maintain a safe distance at all times. Another important safety measure used in this robot is the use of an infrared sensor at the back which stops the robot from moving Backward when any object is detected at the rear stops the movement of the robot.

With the purpose of increasing its usability, Wi-Fi capability is included in the controller using an ESP32 Wi-Fi module. Therefore, robot can operate automatically or be controlled by manually. As such, it increases adaptability in various scenarios in industries. The system will employ an L298N motor driver to power the robot. The robot will effectively carry medium amounts of cargo.

The developed system aims to develop a simple, reliable, affordable and safe material handling robot with several functionalities such as human following, automatic obstacle avoidance and safety measures to ensure safety from the robot at all times.

II. LITERATURE SURVEY

In recent times, the development of human-following robots has Developed consideration of attention for the numerous

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practical applications in industrial automation, healthcare, and personal assistance. Some robots are equipped with capabilities of detecting and following a human target at a safe distance in real time. These systems ensure enhanced efficiency while reducing human effort in various settings :contentReference[oaicite:0]index=0.

A number of studies conducted by scholars on designing human-following robots using low-cost microcontrollers along with ultrasonic and infrared sensors. For instance, one of the experiments conducted utilized ultrasonic sensors to detect distances, and IR sensors to detect the direction of movement in the human being. The robot has capable of tracking a person based on the sensor inputs :contentReference[oaicite:1]index=1.

In addition, a motion-sensing-based robot is designed using ultrasonic sensors to keep a fixed distance between the robot and the human, and infrared sensors to detect the direction of motion. The robot has the capability to move forward and turn towards the left and right based on sensor input data.

The sensors are have found widespread application in their systems because they are inexpensive, require less energy and can detect the presence of any object irrespective of the lighting environment. However, research reveals that ultrasonic sensors can be unreliable under specific circumstances when detecting objects such as uneven surfaces :contentReference[oaicite:3]index = 3.

In recent times, innovations have seen a shift towards employing multiple ultrasonic sensors and visual sensing mechanisms for greater reliability. For example, systems involving the use of multiple ultrasonic sensors can detect obstacles and track humans from various directions :contentReference[oaicite:4]index=4. Another technique involves the use of artificial intelligence and cameras to identify and track individuals.

Even though all this development have been made, most of all the existing systems still do not have inbuilt safety features especially for detecting rear side collision. They do not offer users the option of switching between automatic and manual mode of control as well.

In the view of these weaknesses in previous systems, it is intended to develop of cost-effective robotic system that can follow humans, detect obstacles, detect rear side collision using infrared sensor, and control manually via WiFi from ESP32 module.

III. PROBLEM DEFINITION

In many manufacturing facilities, manual lifting of heavy loads over short to medium distances is mandatory. Such activities cause physical strain and may lead to injury in the workplace. Small and medium enterprises find it difficult to implement full automation due to high implementation costs and complexity.

The current technology used in the design for robotic systems that perform material transportation is sophisticated and costly, with most using vision-based systems as well complex navigation algorithms that cannot be employed cheaply. Most robots lack necessary safety measures such has the ability to sense obstacles from behind.

Furthermore, majority of the existing systems operate in one of two ways, either on full autonomous operation or manual operation; however, they do not have the capability of operating on both modes simultaneously.

This implies that there is a necessity to create an economical, efficient, and safe robotic system that will be able to help in carrying loads in industries. The system must be able to follow a human being, detect obstacles while moving, have safety in terms of detecting obstacles behind the robot, and have the capability of operating in autonomous and manual modes.

IV. OBJECTIVES

The primary objectives of this project are as follows:

- Design and develop a low-cost autonomated industrial load-carrying robot using the STM32 microcontroller.
- To implement human-following functionality using sensors, enabling the robot to track and assist a human operator.
- To incorporate obstacle avoidance and detection using an ultrasonic sensor for safer navigation.
- To enhance system safety by integrating a rear-mounted infrared sensor for automatic shutdown when an object is detected behind the robot.
- To develop a dual-mode operation system that supports both autonomous navigation and manual control using an ESP32-based Wi-Fi module.
- To ensure efficient load carrying while maintaining system stability and reliability.
- To provide a scalable and practical solution suitable for small- and medium-scale industrial applications.

V. METHODOLOGY

The design of the system involves the application of the idea of embedded control systems that include the elements involved in loading and transporting loads autonomously. The whole process includes four steps, which include system operations, sensor integration, control algorithms, and communication protocol development.

A. System Operation

The robot functions in two modes: autonomous mode and manual mode. When functioning in autonomous mode, the robot follows the commands of the human user and avoids obstacles using its sensors. The robot can be remotely controlled when in manual mode using the ESP32 board.

B. Sensor Integration

An ultrasonic sensor is mounted at the front of the robot for obstacle detection and determining the distance from the robot to the person. In this way, the robot can keep the safe distance when tracking the person. An IR sensor is mounted at the back of the robot to detect any objects near to the robot. If the robot senses any object at its back, then it stops immediately.

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C. Control Logic

The STM32 is the microcontroller that forms the main control mechanism. The microcontroller receives input from the ultrasonic and infrared sensors and analyzes this data to find out how the robot should move. I to move forward, turn, stop, or follow a human being. The pulse width modulation will control the speed and direction of rotation of motors by making use of L298N motor driver.f some values are above some threshold level, the microcontroller will make the robot

D. Communication Mechanism

The ESP32 module is incorporated into the system to facilitate wireless communication. This enables the user to control the robot through Wi-Fi using the Mobile. The command sent to the ESP32 board will be forwarded to the STM32 board, which will execute the command through the motor.

E. Operational Flow

The robot first stays in the idle state and keeps checking its sensors. Once the presence of any human being inside the predetermined distance range is detected by the robot, then the robot enters into the human following state. In case the robot finds any obstacle in its way, it enters into the obstacle avoiding state. In case there is any object behind the robot detected by the rear IR sensor, the robot immediately stops itself to prevent any damage.

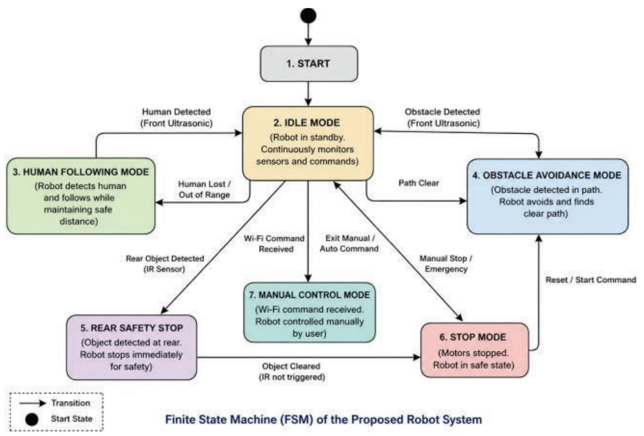

Fig. 1. Finite State Machine (FSM) of the proposed robot system

VI. SYSTEM ARCHITECTURE

The system architecture design flow has been proposed to incorporate the functions of the sensor module, processing module, control module, and communication module into an embedded system. The proposed architecture for the autonomous industrial robot in system includes the STM32 microcontroller as the processing unit, sensors for detecting the environment, a motor driver for driving the actuator, and a wireless WI-FI communication module for remote controlling the robot by manual control.

The STM32 microcontroller will be utilized as the main controller Process for Processing Data Obtained from Sensors and Applying Control Algorithms. The ultrasonic sensor is to be placed at the front of the robot for detect distance calculate and obstacles avoidance, as well as for facilitating follow-me functionality. The IR (Infrared Sensor) this sensor will be located at the rear of the robot for providing a mechanism to stop immediately when any object is detected around it.

The L298N motor driver module controls the robot's DC motors. Control signals generated by the STM32 blue pill drive the motors, enabling the robot to perform forwards and backwards motion and turn right and left directions. The speed of the motor is controlled using PWM signals.

ESP32 Module for Manual Control To allow the robot to contol the manually using (Mobile), an ESP32 module is incorporated into the design. The ESP32 supports Wi-Fi communication capabilities, allowing the robot to be controlled remotely via the Wi-Fi interface. The command is received through the Wi-Fi interface and processed by the STM32 processor to drive the motors.

Power Supply for the Robot All the components in the robot are powered by a rechargeable battery All power supply distributrd by by using the BUck converter (for the voltage constant) mounted on the robot chassis.

This ensures smooth and reliable operation.

VII. SYSTEM ARCHITECTURE

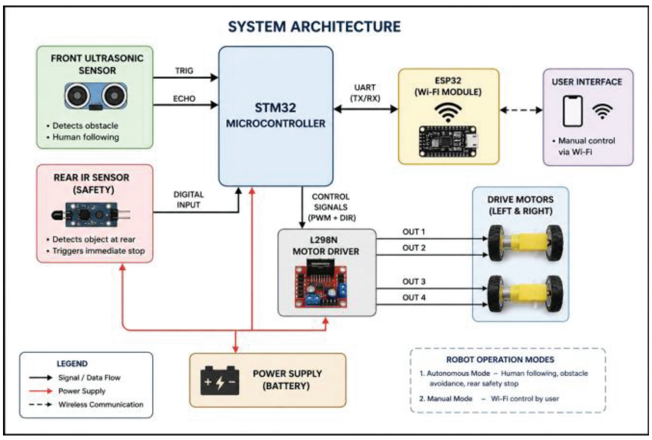

Fig. 2. System architecture of the autonomous load-carrying robot

VIII. SOFTWARE USED

The proposed autonomous industrial load-bearing robot require the employment of different software programs for configuration, coding, debugging, and testing. Below are the different software programs employed in this particular project:

- **STM32CubeMX:** Used for configuring the STM32 microcontroller peripherals such as GPIO, timers, and communication interfaces. It simplifies initialization code generation and reduces development time.

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- **STM32CubeIDE:** An integrated development environment used for writing, compiling, and debugging embedded C code for the STM32 microcontroller. It provides support for HAL libraries and real-time debugging.
- **Embedded C:** The programming language used to implement the control logic, sensor interfacing, and motor control algorithms.
- **ESP32 Arduino IDE / ESP-IDF:** Used for programming the ESP32 module to enable Wi-Fi-based communication and manual control of the robot.
- **Serial Monitor / Debugging Tools:** Used to check sensor readings, debug communications between STM32 and ESP32, and evaluate system efficiency.
- **Proteus / Simulation Tools (Optional):** Used for simulating simple circuits and validating hardware circuitry design prior to its

IX. HARDWARE USED

The suggested robot that will autonomously carry loads in the industry is based on embedded hardware components. The following are the major hardware components of the proposed system:

- **STM32 Microcontroller (Blue Pill - STM32F103C8T6):** Serves as the central processing and controlling unit of the whole system. It can processes sensor inputs, executes the control algorithms, and generate the control signals for motor operation and the whole system working.
- **ESP32 Wi-Fi Module:** Provides wireless communication capability, enabling manual control of the robot through using the Wi-Fi with the connection of the mobile phone.
- **L298N Motor Driver:** The Motor Driver used to control the direction and speed of DC motors of the Autonomous vehicle. It can receives control signals from the STM32 and and The ESP 32 drives the motors accordingly.
- **DC Motors (4-Wheel Drive Chassis):** Provide locomotion for the robot. The motors are controlled using PWM signals for speed regulation and directional movement of the Vehicle.
- **Ultrasonic Sensor (HC-SR04):** Used for obstacle detection and distance measurement in the forward direction. It also assists in human-following functionality.
- **Infrared (IR) Sensor:** Mounted at the rear of the robot to detect objects and provide a safety shutdown mechanism for safer way.
- **Battery (Rechargeable Power Supply):** Supplies power to the entire system, including the microcontroller, sensors, and motors.
- **Robot Chassis:** Provides structural support and housing for all components, ensuring stability during load carrying.

X. EXPECTED OUTPUTS

- Robot follows the human operator within a safe distance.
- Detects and avoids obstacles in real time.
- Automatically stops when an object is detected at the rear (safety feature).
- Smooth movement control using STM32 and motor driver.
- Supports Wi-Fi based manual control using ESP32.
- Capable of carrying moderate loads efficiently.

XI. CONCLUSION

This paper discussed the design and improvisation and implementation of an autonomous robotic system with an load-carrying function that is based on the STM32 micro controller. It is noted that system incorporates the functions of following a human being, ultrasonic sensing to avoid collision, and a rear safety mechanism through an infrared sensor.

From the results getting from the experimentation process, it was discovered that the Autonomous vehicle was able to effectively track a human being and detect obstacles while navigating through a given environment. Therefore, the system designed can be viewed as a cost-effective method that minimizes human effort within small-to-medium enterprises.

Further improvement of the robot should concentrate on improving navigation using visual techniques and adopting sophisticated path planning algorithms.

XII. FUTURE SCOPE

- Integration of camera-based human detection using AI techniques.
- Implementation of advanced navigation using SLAM algorithms.
- Addition of load/weight sensing for intelligent load management.
- Development of a mobile application for user-friendly control.
- Enhancement of obstacle detection using LiDAR sensors.
- Incorporation of voice or gesture-based control.
- Improvement in battery efficiency for longer operation time.

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