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Document Transporting System Using Intelligent Robot

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Abstract

The Document Transporting System with Intelligent Robot is an autonomous indoor delivery platform designed to streamline the transfer of documents and stationery within institutional and office environments. The system is built around an ESP32 microcontroller, leveraging its dual-core processing capability, integrated Wi-Fi/Bluetooth modules, and low-power operation for real-time navigation, communication, and system control. Obstacle detection and avoidance are achieved using an array of HC-SR04 ultrasonic sensors, while differential drive locomotion is implemented through high-torque DC motors operated via an L298N motor driver, enabling precise maneuverability in narrow corridors. To ensure secure access, the robot incorporates a capacitive fingerprint sensor for biometric authentication and a solenoid-actuated locking mechanism to safeguard the document compartment. User interaction is facilitated through a voice-recognition module, an LCD/OLED display for status feedback, and GSM-based SMS notifications for delivery updates. A battery management subsystem, powered by a high-capacity rechargeable Li-ion pack with an onboard charging and protection circuit, supports long-duration operation and real-time battery-level monitoring. The integration of embedded control, sensor fusion, biometric security, and wireless communication enables fully automated document delivery with minimal human intervention. This system significantly reduces manual workload, enhances security and traceability, and demonstrates a scalable approach to smart-campus and smart-office automation.

Keywords: ESP32 microcontroller, Ultrasonic sensors, Obstacle detection, Fingerprint sensor, Solenoid lock, Smart campus, Secure delivery system.

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1. Introduction

In many educational institutions and office environments, the transfer of documents between departments,administrative office and staff rooms is still carried out manually.This project is designed only to transfer the documents in the staffrooms and HOD’s cabin and to departments are the future designs.Important materials such as circulars, exam papers, official letters, and reports are often delivered by support staff, which can lead to delays, inefficiencies, and unnecessary workload. This repetitive task consumes valuable human resources that could be better utilized for more critical academic or administrative work. As institutions move toward digital transformation and smart campus frameworks, there is a growing need for an efficient, reliable, and secure method for handling internal document transportation.

Manual document handling also presents several challenges, including scheduling conflicts, fatigue, and the unavailability of staff. Human errors can result in misplaced or delayed documents, while confidential materials may be at risk during physical handling. Traditional systems generally lack proper tracking and delivery confirmation, making it difficult to verify whether documents have reached their intended destination. These limitations highlight the need for an automated, precise, and traceable solution that can operate consistently without depending on human intervention.

Advancements in robotics and embedded systems provide an effective approach to solving these issues. Intelligent robots are increasingly being used across various domains to automate repetitive and time-consuming tasks, improving productivity and ensuring greater accuracy. In institutional environments, robotic automation enables secure and consistent document delivery while supporting smart campus initiatives. By integrating sensors, microcontrollers, and autonomous navigation technologies, such robots can navigate hallways, avoid obstacles, and deliver documents efficiently. Automation of this process allows human staff to focus on higher-level responsibilities, promotes digital transformation, and enhances overall workflow management. Implementing a robotic document transporting system aligns with modern Industry 4.0 principles and serves as a significant step toward building efficient, intelligent, and fully automated campuses.

1.1 Objectives

The primary objective of this project is to design and develop an intelligent robotic system capable of autonomously transporting documents and stationery items within an institutional environment. The robot is intended to ensure safe, secure, and timely delivery while significantly reducing human effort. It must be capable of obstacle detection, secure access authentication, and autonomous navigation using embedded systems technology. By integrating IoT-based communication features such as Wi-Fi or Bluetooth, the system can further enhance monitoring and operational efficiency. Achieving this objective supports the development of smart, automated environments within educational institutions and aligns with the broader vision of smart campus initiatives.

The specific objectives of the project include developing an embedded control system using the ESP32 microcontroller, integrating sensors for environment detection, and implementing fingerprint-based security to ensure authorized access. Another key objective is to design efficient motion control using motor drivers while optimizing power consumption for continuous robot operation. The project also focuses on simulation and testing to validate circuit design, sensor response, and system behavior under varying conditions before physical implementation. Additionally, the work aims to establish a modular and upgradable architecture that can support advanced features such as AI-based navigation and multi-robot coordination in future phases.

2. Methodology

The methodology followed in this project involves a systematic approach that integrates hardware design, software development, simulation, and testing to build an intelligent robotic system for document transportation. The process begins with understanding institutional requirements and defining the functional specifications of the robot, including autonomous navigation, obstacle detection, secure storage, and user authentication. Based on these requirements, the system architecture is designed by selecting appropriate components such as the ESP32 microcontroller, ultrasonic sensors, DC motors, motor drivers, fingerprint sensor, solenoid lock, display unit, and rechargeable battery.

The hardware development phase includes assembling all sensors and actuators, designing the motor control circuitry, and establishing power management for stable operation. The ESP32 microcontroller is programmed to handle navigation logic, sensor data processing, security authentication, and communication tasks. Obstacle detection algorithms are implemented using ultrasonic sensors, allowing the robot to adjust its path and avoid collisions. The fingerprint module is integrated to ensure authorized access to the storage compartment, while the solenoid lock provides secure enclosure control. Communication features such as Wi-Fi/Bluetooth and optional SMS notification are configured to allow user interaction and system monitoring.

Before physical implementation, simulation tools are used to verify the circuit design, sensor behavior, and control algorithms. Block diagrams, flowcharts, and system models are prepared to validate logical operation and identify potential issues. Once verified, the complete system is assembled and tested in a controlled environment to evaluate navigation accuracy, obstacle avoidance, security response, and battery performance. Iterative testing and calibration are performed to refine motor control, improve sensor sensitivity, and enhance overall system reliability. The final stage involves real-time testing within institutional corridors to ensure the robot can autonomously transport documents safely and efficiently. This structured methodology ensures that the proposed embedded robotic system meets the objectives of secure, reliable, and automated document delivery.

2.1 System design

The system is built around an ESP32 microcontroller, which controls all operations of the robot. Ultrasonic sensors detect obstacles and help the robot navigate safely. The movement is provided by DC motors, driven through a motor driver module. A fingerprint sensor is used to verify authorized users, and a solenoid lock secures the document compartment. For communication and updates, the robot uses voice recognition, GSM/Wi-Fi notification, and a display unit that shows battery status and delivery information. All components are powered by a rechargeable battery, making the robot fully portable. The entire system combines navigation, security, communication, and control to automate document delivery efficiently.

3. Block Diagram

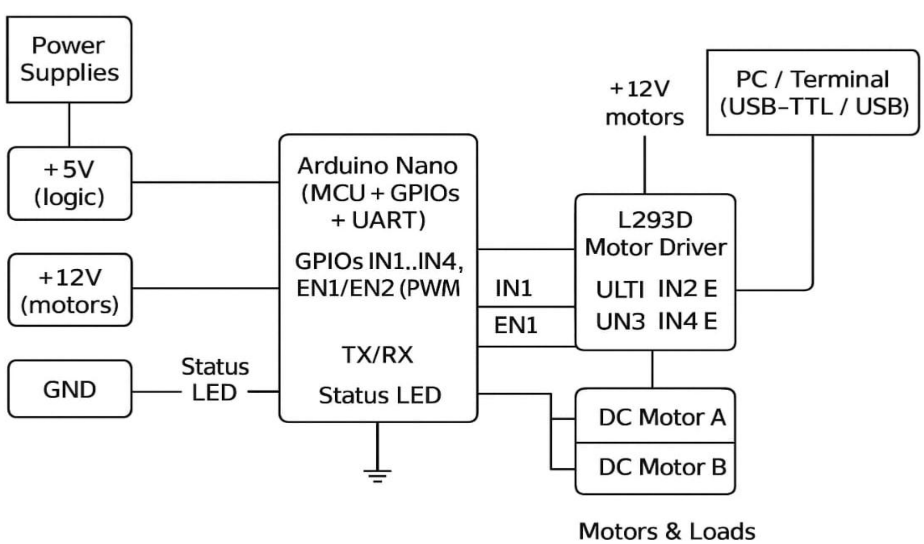

Figure 1: Block Diagram

The block diagram of Document transporting system with intelligent robot represents the control system for an autonomous robot using an Arduino Nano and L293D motor driver.

1. Power Supply

Provides +5V for Arduino logic and +12V for driving the motors.A common GND is shared by all components.A status LED is connected to indicate power or system status.

2. Arduino Nano (Main Controller)

Acts as the brain of the system.Uses GPIO pins (IN1–IN4) and EN1/EN2 (PWM) to send control signals to the motor driver.TX/RX pins connect to a PC via USB-TTL for programming and data communication.

3. L293D Motor Drive

Receives control signals from the Arduino (IN1, IN2, IN3, IN4).Takes 12V motor power and distributes it to the motors. it controls the motor direction and motor speed (using PWM from EN1/EN2).

4. DC Motors (A & B)

Two motors are connected to the motor driver.Based on Arduino commands, the robot can move forward, backward, left, or right.

5. PC / Terminal

Used for uploading code and monitoring data through USB-TTL or USB.

4. Working Principle

Its working principle is structured as follows:

4.1. System Initialization

The ESP32 microcontroller powers up and initializes all sensors and modules including the ultrasonic sensor, fingerprint sensor, motor driver, and display unit.The battery management system checks voltage levels and updates the display.

4.2. User Authentication & Compartment Access

The fingerprint sensor continuously scans for a registered fingerprint.When an authorized user is detected, the ESP32 signals the MOSFET driver to energize the solenoid lock, unlocking the storage compartment for loading or unloading documents.Unauthorized fingerprints are rejected to ensure security.

4.3. Navigation & Motion Control

After loading, the robot begins movement based on pre-defined path logic or manual command.The ESP32 controls the L298N motor driver, regulating the speed and direction of the two DC motors (differential drive).Real-time sensor feedback helps the robot maintain stability and proper orientation.

4.4. Obstacle Detection & Avoidance

Ultrasonic sensors continuously measure distance from surrounding objects.When an obstacle is detected within a threshold (e.g., <20 cm), the controller stops the robot,evaluates alternate safe directions, navigates around the obstacle.This ensures collision-free, safe movement within campus corridors.

4.5. Delivery Confirmation & Communication

Upon reaching the destination, the robot stops and sends an SMS notification or voice alert to the recipient. The fingerprint sensor verifies the authorized receiver before unlocking the solenoid lock for document collection.The display unit shows status messages such as "Arrived," "Waiting for Verification," and "Delivery Completed."

4.6. Return & Power Management

After delivery, the robot returns to its docking/start location either by navigation logic or remote command.Battery status is continuously monitored; low-battery warnings are shown on the display to prompt recharging.

5. Circuit Diagram

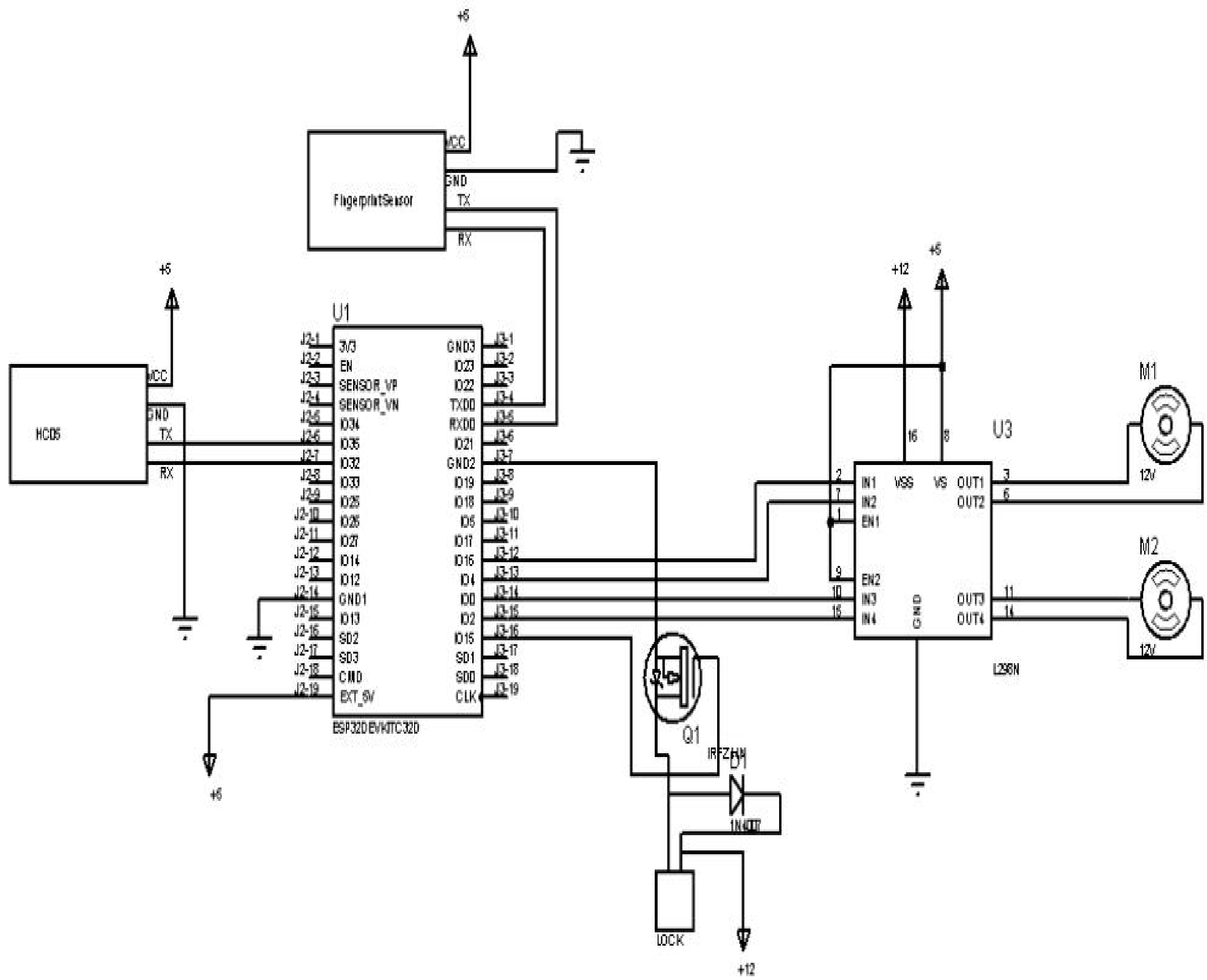

Figure 2: circuit diagram of document transporting system with intelligent robot

5.1 Simulation Diagram

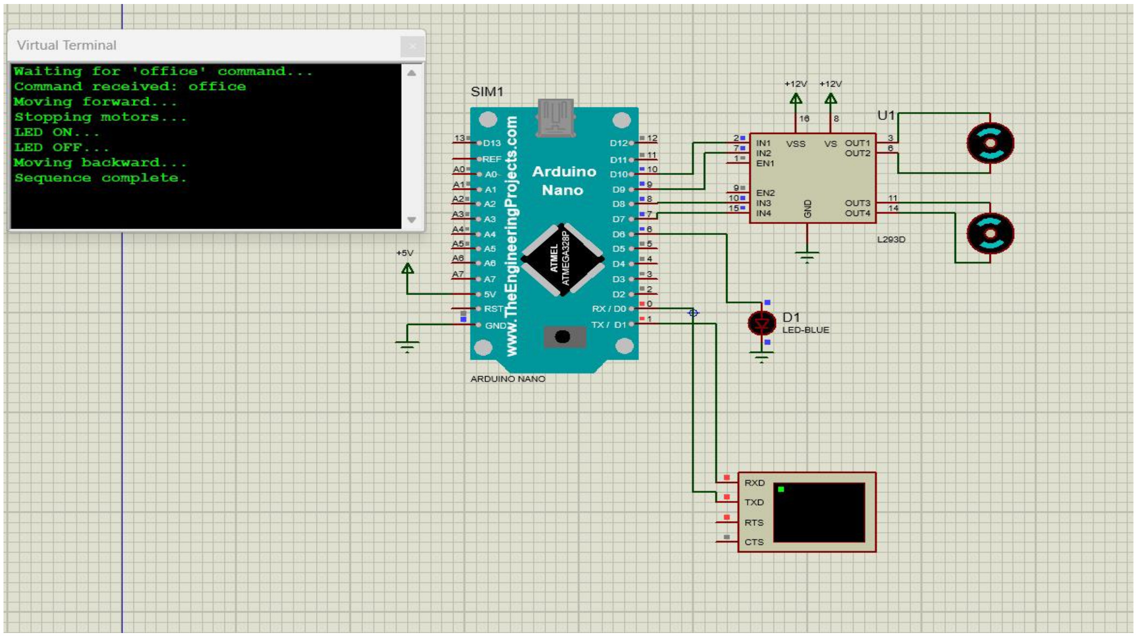

Figure 3: Simulation Diagram

6. Hardware

Figure 4: Hardware of Document transporting robot

The hardware of the Document Transporting Robot consists of an Arduino Nano as the main controller, which receives a regulated 5V supply for logic operations, while the DC motors are powered by a 12V supply through an L293D motor driver. The Arduino processes control signals and sends them to the motor driver, which regulates the speed and direction of the motors to enable forward, backward, and turning movements. Status LEDs are used to indicate system operation, and a PC or USB terminal interface allows programming and monitoring of the system. Together, these components ensure stable power, precise motor control, and reliable autonomous movement for transporting documents efficiently within an institutional environment.

7. Conclusion

The designed control circuit successfully integrates the ESP32 microcontroller with a fingerprint sensor, ultrasonic sensor, L298N motor driver, and solenoid lock results in a highly efficient and secure autonomous document-transporting robot. The system not only guarantees confidentiality through biometric verification but also ensures safe navigation using real-time obstacle detection. With the ESP32 serving as the intelligent control hub, all components work seamlessly to manage movement, security, and interaction. This automation setup significantly reduces human intervention, minimizes risks of document misplacement, and enhances operational efficiency. Its compact “mini-store” design allows the robot to securely hold and deliver documents to authorized individuals only. Such a system demonstrates great potential for deployment in academic institutions, offices, and other environments where secure, reliable, and smart document handling is essential. It represents a step forward in incorporating robotics and IoT technologies into everyday workflows, promoting convenience, safety, and technological advancement.

8. Future Scope:

The Autonomous Document Transporting Robot can be widely used in colleges, offices, and hospitals to deliver documents and small items efficiently. Future upgrades could include IoT integration, AI-based navigation, facial recognition, and expanded delivery capabilities for food, lab equipment, or stationery. It can reduce human effort, enable contactless delivery, and be adapted for commercial or industrial logistics.Other than that this project is designed only to carry the documents with the department from Hod’s cabin to staffroom but ,in future it will designed in such a way that the documents can be carried to other departments by climbing the stairs.

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