

Bidirectional Counter Smart Gate

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Abstract

This project presents the design and implementation of a bidirectional smart gate system capable of counting people entering and exiting, authenticating access via NFC, controlling entry through a servo motor, and logging events with a camera. Data is transmitted to a cloud MQTT broker and visualized through Node-RED dashboards, with emergency alerts sent via Telegram and email.

Introduction

The increasing demand for secure and reliable access control systems motivated the development of this smart gate. The system not only tracks occupancy but also integrates authentication, remote monitoring, and automated alerts. The primary objectives are bidirectional counting, NFC-based authentication, gate automation, and IoT data integration.

System Overview

The system consists of ultrasonic sensors for bidirectional counting, an NFC reader for authentication, a servo motor to control the gate, and a Raspberry Pi as the central controller. Events are logged with a Pi camera. The collected data is published to a HiveMQ MQTT broker and processed by Node-RED for visualization, alerts, and CSV logging.

Hardware Components

Component	Description
Raspberry Pi	Main controller running Python and MQTT client
Ultrasonic Sensors	Detect entry and exit for bidirectional counting
PN532 NFC Module	Provides card-based authentication
Servo Motor	Controls the gate (open/close mechanism)
Camera Module	Captures images of denied access attempts

Software Architecture

The Raspberry Pi runs Python code using libraries such as GPIOZero, Adafruit PN532, and Paho MQTT. Node-RED is used for real-time data processing, dashboard visualization (gauges and charts), and emergency notifications via Telegram and email. Data is also logged into CSV files for further analysis with Python (Matplotlib, Pandas).

System Workflow

1. A person approaches the gate and is detected by ultrasonic sensors.
2. If entering, the system requests NFC authentication.
3. If the card is valid, the servo opens the gate and the entry is counted.
4. If invalid, the camera captures an image and access is denied.
5. Exit is detected automatically without NFC.
6. Data (inside, entered, exited counts) is published to MQTT.
7. Node-RED processes data for visualization and alerts.

Dashboard & Notifications

Node-RED provides a dashboard with gauges and charts displaying occupancy, entries, and exits. In case of unauthorized access attempts or abnormal occupancy, notifications are sent to a Telegram bot and via email. Data is also stored in CSV files for historical tracking.

Testing & Results

The system was tested in multiple scenarios: single entry, multiple entries, unauthorized access, and exits. The counters updated correctly, unauthorized access was blocked, and alerts were successfully sent. The Node-RED dashboard displayed real-time occupancy, and CSV logs were generated as expected.

Conclusion & Future Work

This project successfully integrated hardware and IoT tools to create a functional bidirectional smart gate. Future improvements include integrating face recognition for enhanced security, using a cloud database for scalable storage, and deploying a web-based dashboard for remote monitoring.