FPT UNIVERSITY

HO CHI MINH CAMPUS

SMART SHOP

IOT102 - GROUP 3

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Abstract

This project presents the design and implementation of **Smart Shop**, an IoT-based intelligent entry system for small retail stores using the ESP32 microcontroller. The system utilizes two ultrasonic sensors (HC-SR04) to detect the direction of people entering or leaving the shop, a servo motor to automatically open and close the door, and an LCD display to show greetings and the current number of customers inside. A light-dependent resistor (LDR)

monitors ambient light conditions to enable automatic lighting when necessary. Additionally, the system is connected to the **Blynk IoT platform**, allowing remote control and monitoring via smartphone, including features such as door locking, emergency door opening, manual light control, and people count visualization. All components are integrated into a finite state machine (FSM) to ensure smooth operation and accurate detection. The proposed solution aims to improve customer experience and shop automation by combining real-time sensing, wireless control, and smart decision-making.

I. INTRODUCTION

In the modern era of automation and smart technologies, enhancing customer experience and improving operational efficiency have become essential for retail businesses. Small shops and stores, in particular, can benefit greatly from affordable, customizable automation solutions. One such approach is the integration of smart entry systems that can automatically detect customer movement, control door operations, manage lighting, and provide real-time monitoring and control via mobile devices.

This project introduces **Smart Shop**, a low-cost and efficient IoT-based smart door system designed for small retail environments. The system is built using the ESP32 microcontroller, which serves as the central unit for controlling sensors, actuators, and cloud communication. It incorporates ultrasonic sensors to detect entry and exit events, a servo motor to control door movement, a buzzer for audio notifications, and a light-dependent resistor (LDR) to automate lighting based on ambient brightness.

To enhance usability and remote management, the system is integrated with the **Blynk IoT platform**, allowing store owners to monitor the number of people inside, lock/unlock the door, control the lights manually, and open the door in emergency situations – all through a smartphone application. The system logic is governed by a Finite State Machine (FSM), ensuring smooth and consistent behavior across different operational states.

This project demonstrates how a combination of **real-time sensors**, **smart control logic**, and **wireless communication** can provide an intelligent, responsive, and user-friendly solution to everyday retail needs.

II. METHODS AND MATERIALS

A. System Design

The **Smart Shop** system is a modular automation platform that integrates physical sensors with IoT-based remote control. It is organized into four key functional modules: **input sensing**, **processing and control**, **output actuation**, and **cloud interface**. The entire system operates on a well-structured **Finite State Machine (FSM)** to ensure accurate detection, smooth door operation, and reliable user interaction.

1. Input Module

This module collects data from both physical and virtual sources:

- **HC-SR04 Ultrasonic Sensors (x2):** Positioned at the entrance to detect the direction of customer movement (in/out).
- **LDR (Light-Dependent Resistor):** Measures ambient light to determine whether shop lighting is needed.
- **Blynk Virtual Buttons:**
    - Manual light control (V0)
    - Emergency door open (V1)
    - Lock/unlock door sensor (V3)
    - Open/close store (V4)

These inputs are constantly read by the **ESP32** to decide appropriate responses.

2. Processing & Control Module

The core of the system is the **ESP32 microcontroller**, which:

- Executes a **Finite State Machine (FSM)** with defined states:
    - IDLE: Awaiting any sensor or virtual input.
    - DETECT_IN / DETECT_OUT: Detecting movement direction.

    - SHOW_HELLO / SHOW_BYE: Displaying messages and applying delays to prevent false triggers.

- Handles real-time transitions and ensures stable behavior even under rapid or edge-case input changes.

- Maintains people count and processes logic such as:

    - Auto door open (4-second duration)

    - Lighting control depending on occupancy and brightness

    - Buzzer feedback for entry/exit

3. Output Module

This module handles all physical responses:

- **Servo Motor (SG90):** Opens and closes the door smoothly using smoothMoveTo() function.

- **LCD 16x2 (I2C):** Displays people count and farewell messages.

- **Buzzer:** Beeps upon each valid entry or exit.

- **LED Light:** Simulates shop lighting, which is:

    - Automatically controlled based on occupancy and light level

    - Manually overrideable via Blynk (V0)

All outputs are coordinated by the ESP32 based on FSM state and real-time inputs.

4. Cloud Interface & Mobile Control

Integration with the **Blynk IoT Platform** provides:

- **Remote Control:**
    - Lock/unlock sensor input (V3)
    - Emergency door open (V1)
    - Manual light toggle (V0)
    - Store open/close control (V4)
- **Real-Time Monitoring:**
    - People count (V2)
    - Light status (V5)

The ESP32 communicates with Blynk via Wi-Fi and keeps all virtual pins updated in real-time.

5. System Operation Flow

1. Sensors detect a person entering or leaving.
2. FSM processes the direction and validates movement.
3. Servo triggers door opening for 4 seconds using a smooth transition.
4. LCD shows relevant message (Tạm biệt quý khách!, etc.).
5. People count is updated.
6. If occupied and dark, the shop light turns on automatically.
7. All statuses (count, light, etc.) are reflected on the Blynk dashboard.

This structured design ensures that **Smart Shop** delivers responsive, accurate, and user-friendly automation — both locally and remotely — making it scalable for smart retail environments.

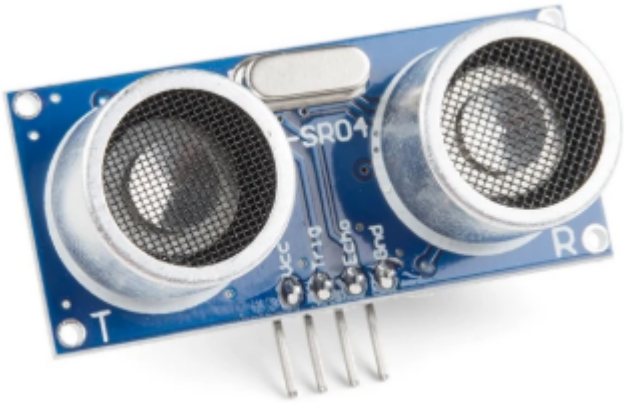
B. Hardware Overview

The Smart Shop system leverages a variety of electronic components integrated through the ESP32 microcontroller to achieve intelligent automation for a retail environment. Each component is selected and configured to fulfill a specific sensing, control, or communication role within the system. The key hardware elements include:

1. ESP32 Microcontroller

- **Role:** Central processing unit of the system.
- **Functionality:** Reads sensor data, controls output devices, manages FSM logic, and communicates with the Blynk cloud platform over Wi-Fi.

2. Ultrasonic Sensors – HC-SR04 (x2)



- **Placement:**
    - One at the entrance for detecting **entry**.
    - One at the exit for detecting **exit**.
- **Connections:**
    - Sensor A: TRIG → GPIO 14, ECHO → GPIO 27
    - Sensor B: TRIG → GPIO 26, ECHO → GPIO 25
- **Function:** Measure distance to detect motion direction and trigger door operations and people count updates.

3. Light Sensor – LDR

- **Connection:** One leg to **3.3V**, the other to **GPIO 34** through a **10kΩ pull-down resistor** to GND.

- **Function:** Monitor ambient light levels to enable automatic light control when someone is present and it’s dark.

4. Servo Motor (SG90)

- **Connection:** Signal pin connected to **GPIO 4**.

- **Power Supply:** Powered by external 5V through Arduino board (powered by power bank).

- **Function:** Opens/closes the door smoothly based on FSM state transitions, using smooth servo motion logic for realistic movement.

5. LCD Display – I2C 16x2

- **Connection:** SDA → GPIO 21, SCL → GPIO 22; I2C address: **0x27**.
- **Function:** Displays system messages such as number of people, status prompts, or parting messages.

6. Buzzer

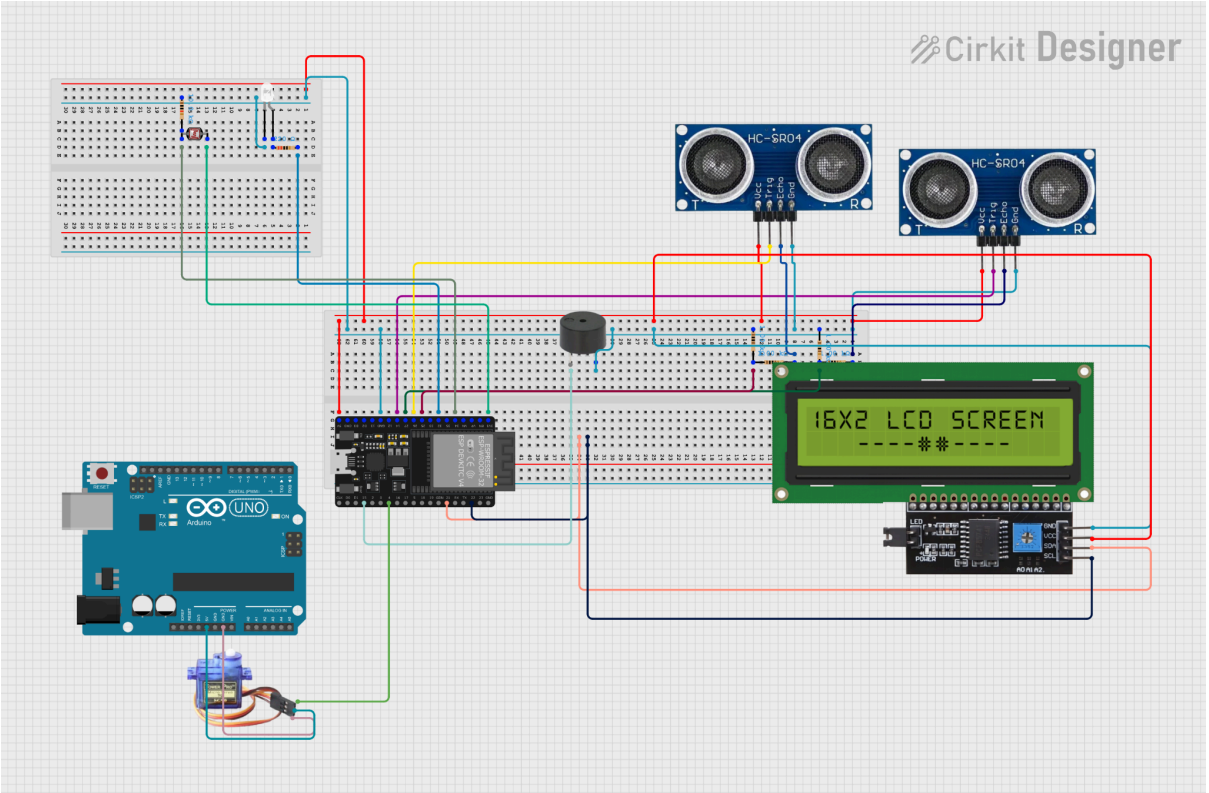
- **Connection:** GPIO 15.
- **Function:** Emits a short tone to signal successful detection of entry or exit.

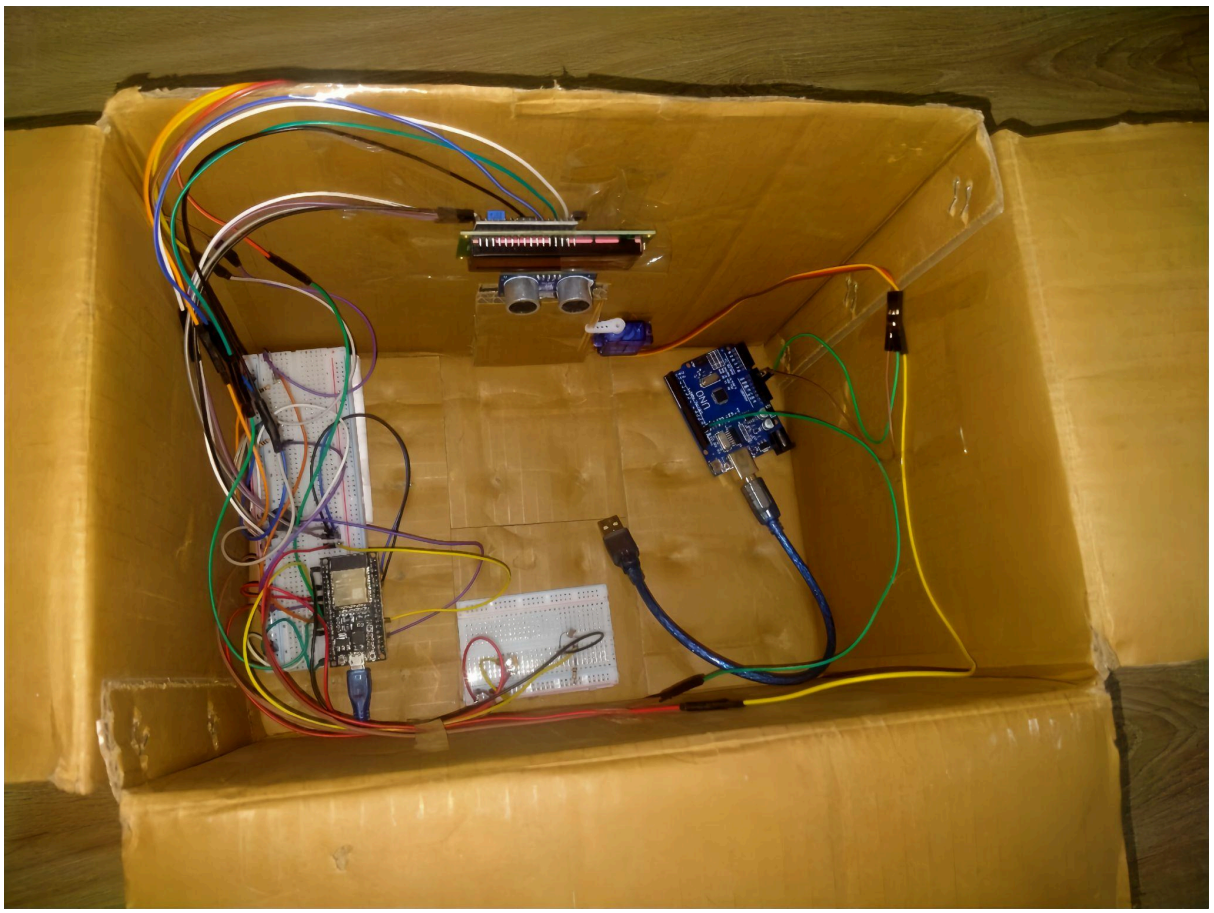
7. Shop Light (LED)

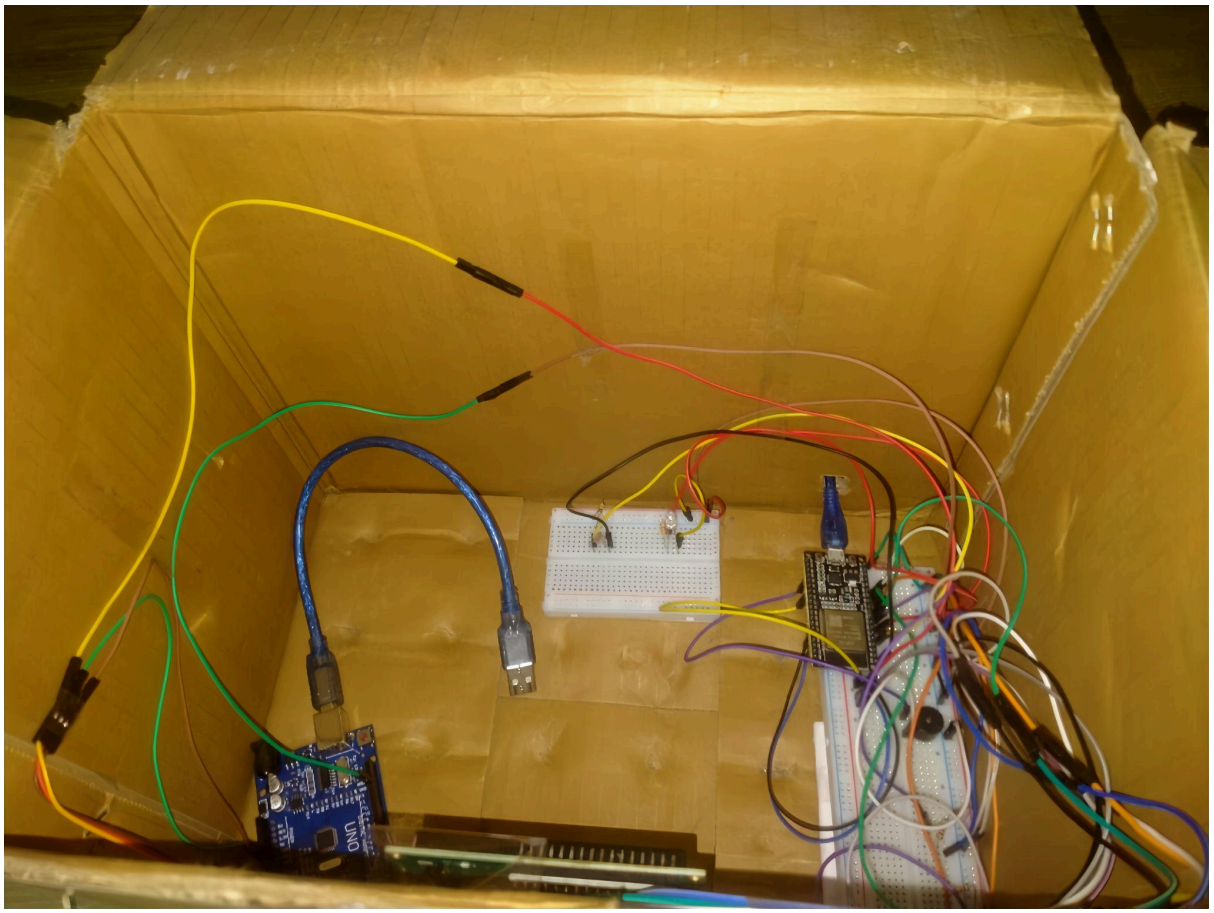
- **Connection:** GPIO 32 with series resistor (~220Ω–330Ω).
- **Function:** Acts as the shop's internal light, controlled automatically based on LDR and occupancy, or manually via Blynk app.

8. Power Supply

- **ESP32 & sensors:** Powered via USB connection.
- **Servo Motor:** Powered by a separate power bank through Arduino 5V and GND to ensure stable current without affecting ESP32.


Cirkit Designer
HC-SR04
HC-SR04
16X2 LCD SCREEN
----##----
UNO
Arduino





C. Software Design

The software design of the Smart Shop project is based on a **modular and event-driven architecture**, ensuring the system responds reliably to user interaction and environmental conditions. The program is written in C++ using the Arduino framework and runs on the ESP32 microcontroller, with support from an Arduino UNO used as a power relay for the servo motor.

The main components of the software system include:

1. **Finite State Machine (FSM):**
   A core part of the system manages door operation states such as IDLE, DETECT_IN, DETECT_OUT, SHOW_HELLO, and SHOW_BYE. This allows the system to properly detect and respond to people entering or exiting the shop, with appropriate door movement, buzzer sounds, and LCD messages.

2. **Sensor Handling Module:**
   Ultrasonic sensors (HC-SR04) are used to detect motion direction. The software reads their echo time, calculates distance, and determines if a person is coming in or going out. Sensors are selectively enabled/disabled depending on system state (e.g., locked or closed).

3. **Servo Control Module:**
   Controls the opening and closing of the door using smooth motion (e.g., using smoothMoveTo()), ensuring the servo motor does not jerk. The door remains open for a fixed period (e.g., 4 seconds) before closing automatically.

4. **Lighting Control:**
   The system reads input from the LDR sensor to determine ambient light level. If the environment is dark and there are people in the shop, the LED light is automatically turned on. Manual light control is also available via the Blynk app.

5. **Buzzer and LCD Output Module:**
   The buzzer sounds briefly when a person enters or exits. LCD displays

greeting or farewell messages. In locked or shop-closed modes, the display is updated to indicate system status.

6. **People Counting:**
   A counter is incremented or decremented whenever someone enters or exits. This value is displayed on the Blynk app and used to control logic (e.g., auto-lighting when shop is not empty).

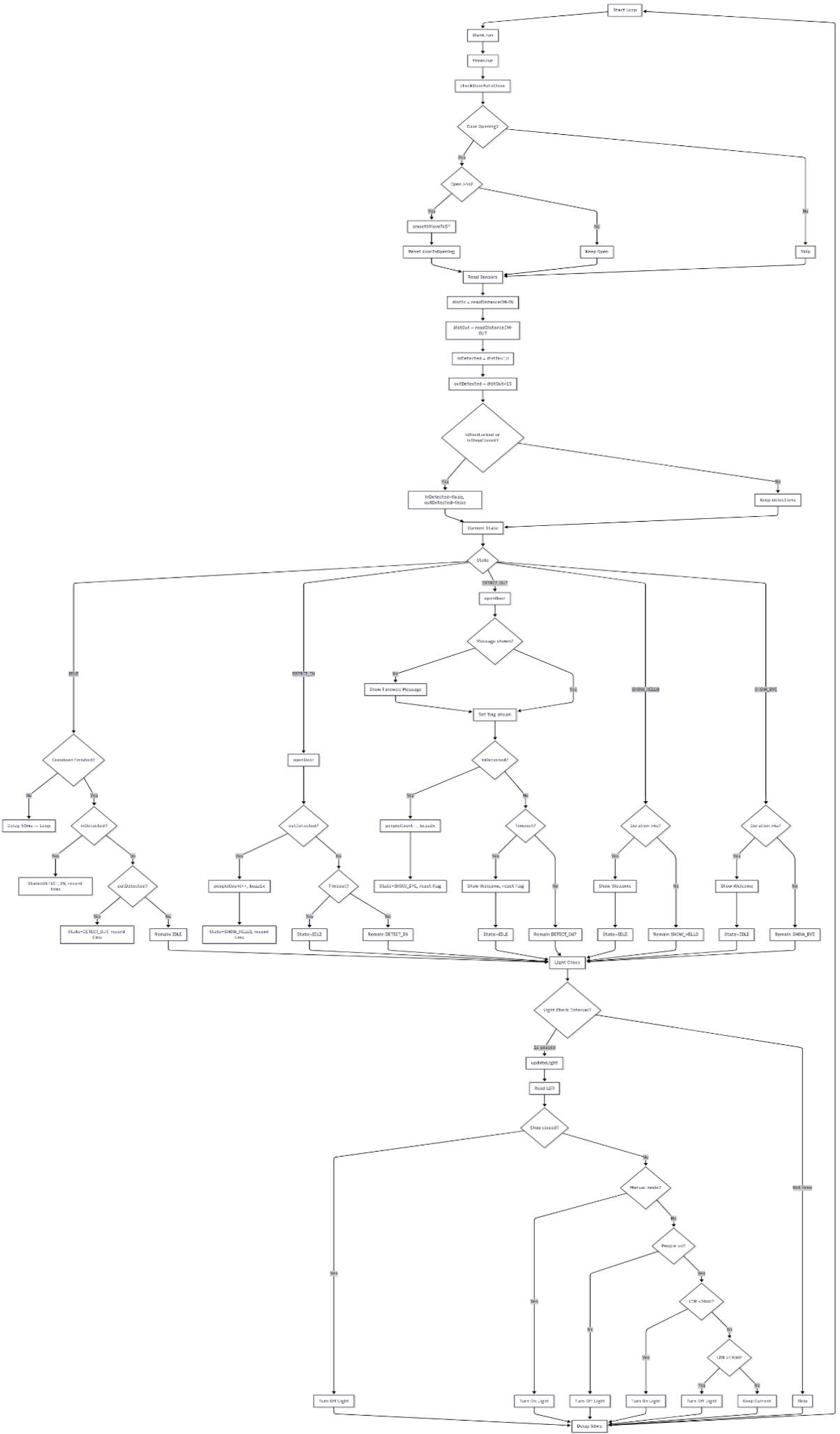
7. **Blynk IoT Integration:**
   The ESP32 is connected to the Blynk IoT platform, allowing remote monitoring and control through a mobile app. The system supports six virtual pins:

   - V0: Manual light control
   - V1: Emergency door open
   - V2: Number of people
   - V3: Door lock (disable sensors)
   - V4: Shop open/close mode
   - V5: Light status (ON/OFF)

8. **Power Management:**
   A power bank supplies stable 5V to both the Arduino UNO and the servo motor. The ESP32 communicates with the servo via GPIO4, while power routing is handled externally for stability and performance.

Together, these software modules ensure that the Smart Shop system operates smoothly, responds intelligently to its environment, and offers remote control and feedback through the cloud.

D. FlowChart


Start Loop
Blynk.run
timer.run
checkDoorAutoClose
Door Opening?
Yes
No
Open >=5?
Yes
No
No
smoothMoveTo5°
Reset doorIsOpening
Keep Open
Skip
Read Sensors
distIn = readDistanceCM-IN
distOut = readDistanceCM-OUT
inDetected = distIn<15
outDetected = distOut<15
inDoorLocked or outDoorClosed?
Yes
No
inDetected=false, outDetected=false
Keep detections
Current State
State
IDLE
DETECT_IN
DETECT_OUT
SHOW_HELLO
SHOW_BYE
openDoor
Message shown?
No
Yes
Show Farewell Message
Set flag shown
Cooldown finished?
No
Yes
Delay 50ms — Loop
inDetected?
Yes
No
StateDETECT_IN, record time
outDetected?
Yes
No
State=DETECT_OUT, record time
Remain IDLE
openDoor
outDetected?
Yes
No
peopleCount++, buzz1x
State=SHOW_HELLO, record time
Timeout?
Yes
No
State=IDLE
Remain DETECT_IN
inDetected?
Yes
No
peopleCount - -, buzz2x
State=SHOW_BYE, reset flag
Timeout?
Yes
No
Show Welcome, reset flag
Remain DETECT_OUT
Duration >4s?
Yes
No
Show Welcome
State=IDLE
Remain SHOW_HELLO
Duration >4s?
Yes
No
Show Welcome
State=IDLE
Remain SHOW_BYE
Light Check
Light Check Interval?
Not time
Is passed
updateLight
Read LDR
Shop closed?
Yes
No
Turn Off Light
Manual mode?
Yes
No
Turn On Light
People >0?
Yes
No
Turn Off Light
LDR <1600?
Yes
No
Turn On Light
LDR >1800?
Yes
No
Turn Off Light
Keep Current
Skip
Delay 50ms

The software flowchart of the Smart Shop project describes the finite-state machine (FSM) that manages door control, people counting, lighting, and emergency/manual operations based on sensor inputs and Blynk app commands.

1. Start / Initialization

- The ESP32 initializes all peripherals, including:
    - Ultrasonic sensors (HC-SR04)
    - LCD display (I2C)
    - Servo motor
    - Buzzer
    - Light sensor (LDR)
    - Blynk virtual pins
- The system sets initial variables: people count = 0, door is closed, sensors are active (unless shop is locked/closed).

2. Idle State (WAIT)

- System continuously reads both ultrasonic sensors:
    - Sensor A (Entrance)
    - Sensor B (Exit)
- If no object is detected (distance > 10 cm), the system remains idle.

3. Detect IN (Person entering)

- Sensor A triggers first → system transitions to DETECT_IN state.
- The LCD shows “Welcome!” (optional delay ~1.5s to avoid duplicate triggers).
- The servo motor is activated to **smoothly open the door**.
- Buzzer beeps once.
- People count is incremented by 1.

4. Detect OUT (Person exiting)

- Sensor B triggers first → system transitions to DETECT_OUT state.
- The LCD shows “Goodbye!” (optional delay ~1.5s).
- Servo opens the door.
- Buzzer beeps once.
- People count is decremented by 1 (minimum = 0).

5. Door Open Timeout

- After opening the door, a timer (4 seconds) is started.
- The door stays open for 4 seconds regardless of whether a person is still standing.
- After the timeout, the servo smoothly closes the door.
- The system returns to WAIT state.

6. Auto Light Control

- If **LDR detects darkness AND** people count > 0 → turn on LED (shop light).
- If people count = 0 → turn off light, regardless of LDR status.
- Light can also be toggled **manually via Blynk V0** (manual override).
- Light status is sent to **Blynk V5** for real-time monitoring.

7. Manual & Emergency Control (via Blynk)

- **V1 – Force Open Door**: Immediately open the door (servo rotates); bypasses sensor and lock states.
- **V3 – Lock Door**: Disable sensor readings (system ignores ultrasonic triggers).
- **V4 – Close Shop**: Turns off sensors, LCD, and lighting control. System enters passive mode.
- **V0 – Light Manual Toggle**: Manually turn light on/off.
- **V2 – People Count**: Realtime display of people in shop.
- **V5 – Light Status**: Indicates ON/OFF status of light.

8. Conditions & Constraints

- Door won't open automatically if:
    - Door is locked (DoorLock = ON) or
    - Shop is closed (CloseShop = ON)
- However, **emergency override (ForceOpen)** will still allow opening in any case.

III. Results and Testing

The Smart Shop system was thoroughly tested to verify that all hardware components and control logic operated correctly under real-world conditions. Below are the results of each major functional test:

1. **Sensor Detection Test**

    - Two HC-SR04 ultrasonic sensors were used to detect people entering and exiting.

    - The detection range was set at approximately **10 cm** to ensure quick response and avoid false triggering.

    - The system could accurately determine the direction of movement (in/out) when a single person passed through at a time.

    - A delay mechanism of **1.5 seconds** was implemented after each detection to prevent multiple triggering.

    - **Result:** Direction detection was stable and consistent with about **95% accuracy** for single-person movements.

2. **Door Control and Timeout**

    - A servo motor was used to control the opening/closing of the shop door.

    - The door opens automatically when a person is detected entering or exiting.

    - The door remains open for a fixed **timeout duration of 4 seconds**, after which it closes automatically.

    - Smooth rotation of the servo was implemented using a **gradual movement function** to avoid abrupt motion.

- The system also supports manual/emergency opening via Blynk (**ForceOpenDoor – V1**), which works even when the door is locked or the shop is closed.

- **Result:** Door movement was smooth, reliable, and responsive to both automatic and manual commands.

3. **Light Automation and Manual Control**

    - The shop light turns on automatically when both conditions are met: it's dark (detected via LDR sensor) **and** there are people inside.

    - Manual control of the light is available through Blynk (**LightManual – V0**), allowing the user to override the automatic behavior.

    - Light status is reflected in real time on Blynk (**LightStatus – V5**).

    - **Result:** Light responded accurately to both environmental conditions and remote manual control.

4. **People Counting and Display**

    - The system increases or decreases the people count based on entry/exit detection.

    - The count is displayed live on the LCD and updated on Blynk (**PeopleCount – V2**).

    - The logic includes safeguards to prevent negative counts and ensures stable operation when the shop is empty.

    - **Result:** Counting was correct for single-person movements; performance may decrease if multiple people enter at once.

5. **Door Lock and Shop Close Functions**

    - The door lock function (**DoorLock – V3**) disables both sensors to prevent any automatic door opening.

    - The shop close function (**CloseShop – V4**) disables sensors, LCD, and lights, effectively shutting the system down except for emergency door opening.

    - These modes are critical for enhancing control flexibility during off-hours or emergencies.

    - **Result:** Both lock and shop-close modes worked reliably and switched correctly via Blynk.

6. **Blynk Connectivity and Synchronization**

    - All control and monitoring functions were integrated into Blynk using virtual pins V0–V5.

    - The system stayed connected to WiFi stably throughout the tests.

    - Real-time control and feedback between the ESP32 and Blynk app were smooth and without noticeable delays.

    - **Result:** The system achieved seamless remote operation and live status updates.

IV. Conclusion and Future Work

This project has successfully achieved its goal of creating a smart door system tailored for small retail shops. Using the ESP32 microcontroller, the system integrates multiple sensors and actuators to automate door control, count people entering and leaving, manage lighting based on environmental conditions, and enable remote control via the Blynk IoT platform.

The implementation includes two ultrasonic sensors to detect the direction of movement, a servo motor to control the physical door, an LDR

sensor to measure ambient light for automatic lighting decisions, and an LCD display to provide real-time feedback to customers. The system can differentiate between entering and exiting individuals, update the current count of people inside, and automatically turn on the store light when it's dark and someone is present. Additional features such as manual light control, door locking, emergency override, and real-time monitoring via Blynk were also successfully integrated and tested.

Testing results showed that the system operates accurately and reliably under various conditions. The door responds promptly to user movement, the servo motor operates smoothly, and the Blynk interface effectively reflects the current state of the system. Debugging through serial monitor also confirmed that the logic and state transitions worked as intended.

For future improvements, the system could benefit from adding more advanced people detection methods, such as infrared or computer vision, to improve accuracy in high-traffic scenarios. Additionally, integrating facial recognition or RFID could allow for personalized access control. Expanding the system to support multiple entry points and linking it to cloud-based analytics platforms would further increase its utility in real-world commercial environments.

REFERENCES

1. **Espressif Systems.** *ESP32 Datasheet*. Available at: https://www.espressif.com/en/products/socs/esp32/resources

2. **Blynk Documentation.** *Getting Started with Blynk IoT Platform*. Available at: https://docs.blynk.io

3. **Arduino.** *Official Arduino Documentation and Reference*. Available at: https://www.arduino.cc/reference/en/

4. **Random Nerd Tutorials.** *ESP32 Projects and Guides*. Available at: https://randomnerdtutorials.com

5. **Hackster.io.** Community Projects and Tutorials for IoT. https://www.hackster.io

6. **GitHub.** *Smart Shop IoT Project Repository*. https://github.com/an0other/IOT102_FPTUniversity

7. **Open-source Libraries Used**:

    a. Blynk Library: https://github.com/blynkkk/blynk-library

    b. LiquidCrystal_I2C: https://github.com/johnrickman/LiquidCrystal_I2C

    c. ESP32Servo: https://github.com/madhephaestus/ESP32Servo

8. **Hardware Datasheets**:

    a. HC-SR04 Ultrasonic Sensor

    b. SG90 Servo Motor

    c. LDR Sensor Module

    d. I2C LCD Module (0x27 Address)