Automated Home Security System

A Comprehensive IoT-Based Solution for Fire Detection, Intrusion Prevention, and Remote Monitoring

Project Report

Contents

1 Introduction

This report presents a comprehensive home security system that integrates multiple IoT devices to provide a robust solution for residential security. The system combines three main components:

1. **Door Security System with Keypad Access Control**: A secure entry system with password protection, remote control capabilities, and automatic locking features.
2. **Fire and Intrusion Detection System**: A multi-sensor system that monitors temperature, smoke levels, and vibration to detect potential fires or break-ins.
3. **Camera-Based Motion Detection System**: A visual monitoring system that captures images when motion is detected and provides a live video stream for remote surveillance.

The integrated system leverages the ESP32 microcontroller platform, along with various sensors, actuators, and communication protocols to create a cohesive security solution. The system can be monitored and controlled remotely through mobile applications and web interfaces, providing homeowners with peace of mind and immediate alerts in case of emergencies.

2 System Architecture

2.1 Overview

The home security system follows a distributed architecture with three main subsystems that communicate with each other and with cloud services. Each subsystem is built on an ESP32 microcontroller, which provides the necessary processing power, wireless connectivity, and I/O capabilities.

2.2 Door Security Subsystem

The door security subsystem controls access to the home through a keypad-based authentication system. It includes:

- ESP32 microcontroller for processing and connectivity
- 4×3 matrix keypad for PIN entry
- 16×2 LCD display for user feedback
- Servo motor for door lock actuation
- Buzzer for audible feedback and alarms
- Blynk IoT integration for remote control

2.3 Fire and Intrusion Detection Subsystem

This subsystem continuously monitors for potential fire hazards and unauthorized entry attempts:

- ESP32 microcontroller for processing and connectivity
- DHT11 temperature sensor for heat detection
- MQ2 gas sensor for smoke detection
- Vibration sensor for intrusion detection
- LED indicator for visual status feedback
- Firebase integration for data logging
- Blynk IoT integration for alerts and monitoring
- ESP-NOW protocol for local communication with other subsystems

2.4 Camera-Based Motion Detection Subsystem

This subsystem provides visual monitoring and recording capabilities:

- ESP32-CAM module with integrated OV2640 camera
- PIR motion sensor for movement detection
- Web server for remote access to live stream and captured images
- HTTP streaming server for continuous video feed

2.5 Communication Protocols

The system utilizes multiple communication protocols:

- **WiFi**: For internet connectivity and remote access
- **ESP-NOW**: For local communication between ESP32 devices
- **HTTP/HTTPS**: For web interfaces and API communication
- **MQTT** (via Blynk): For real-time messaging and notifications

2.6 Cloud Services

The system integrates with two cloud platforms:

- **Blynk IoT Platform**: For mobile app control, monitoring, and notifications
- **Firebase Realtime Database**: For data logging, event history, and user authentication

3 Hardware Components

3.1 Microcontrollers

- **ESP32 Development Board**: Used in the door security and fire detection subsystems
- **ESP32-CAM Module**: Used in the camera-based motion detection subsystem

3.2 Sensors

- **DHT11 Temperature Sensor**: Measures ambient temperature for fire detection
- **MQ2 Gas Sensor**: Detects smoke and combustible gases
- **Vibration Sensor**: Detects physical disturbances for intrusion detection
- **PIR Motion Sensor**: Detects movement for camera activation
- **4×3 Matrix Keypad**: User input device for PIN entry

3.3 Actuators and Output Devices

- **Servo Motor**: Actuates the door locking mechanism
- **16×2 LCD Display**: Provides visual feedback for the door security system
- **Buzzer**: Provides audible feedback and alarms
- **LED Indicator**: Visual status indicator for the fire detection system
- **OV2640 Camera**: Captures images and video for the motion detection system

3.4 Power Supply

Each subsystem requires a stable 5V power supply, which can be provided through:

- USB power adapters
- Lithium-ion battery packs with voltage regulators (for backup power)

4 Software Implementation

4.1 Door Security System

The door security system implements a PIN-based authentication mechanism with remote control capabilities through the Blynk platform.

4.1.1 Key Features

- 4-digit PIN authentication
- LCD feedback for user interaction
- Servo-controlled door lock
- Audible feedback with different tones for various events
- Intrusion detection after multiple failed attempts
- Remote locking/unlocking via Blynk app
- Automatic re-locking after a timeout period

4.1.2 Code Structure

The door security system code is organized into several functional blocks:

```
#define BLYNK_TEMPLATE_ID "TMPL3sPoYK4kL"
#define BLYNK_TEMPLATE_NAME "Door Security"
#define BLYNK_AUTH_TOKEN "WQ10MOAWIpFoyGxs13zpNuDB17hnqxog"

#include <WiFi.h>
#include <WiFiClient.h>
#include <BlynkSimpleEsp32.h>
#include <Keypad.h>
#include <LiquidCrystal.h>
#include <ESP32Servo.h>

// WiFi credentials
char ssid[] = "Arpit";
char pass[] = "qwertyuiop";

// LCD configuration (RS, E, D4, D5, D6, D7)
LiquidCrystal lcd(21, 22, 18, 19, 23, 5);

// Servo motor
Servo myservo;
const int servoPin = 4;

// Password system
String password = "8008";
String input = "";
const int passwordLength = 4;
int failedAttempts = 0;

// Buzzer pin
const int buzzerPin = 13;
```

Listing 1: Door Security System - Main Configuration

4.2 Fire and Intrusion Detection System

The fire and intrusion detection system continuously monitors environmental conditions and physical disturbances to detect potential hazards.

4.2.1 Key Features

- Temperature monitoring for fire detection
- Smoke/gas detection for early fire warning
- Vibration detection for intrusion alerts
- Multi-stage alert system based on severity
- Real-time data logging to Firebase
- Push notifications via Blynk
- Local communication with other subsystems via ESP-NOW

4.2.2 Code Structure

The fire detection system code implements a sophisticated monitoring and alerting mechanism:

```
#define BLYNK_TEMPLATE_ID "TMPL3uHRYGepR"
#define BLYNK_TEMPLATE_NAME "Fire and Intrusion Detection System"
#define BLYNK_AUTH_TOKEN "Zysfr47HgmE1ExIM-y9bYkojEdCsNgSV"

#include <WiFi.h>
#include <BlynkSimpleEsp32.h>
#include <esp_now.h>
#include <DHT.h>
#include <Firebase_ESP_Client.h>
#include "time.h"
#include "addons/TokenHelper.h"
#include "addons/RTDBHelper.h"

// Pins
#define DHTPIN 4
#define DHTTYPE DHT11
#define MQ2_PIN 32
#define LED_PIN 22
#define VIBRATION_PIN 2

// Thresholds
#define SMOKE_STAGE1 400
#define SMOKE_STAGE2 800
#define SMOKE_STAGE3 1200
#define TEMP_STAGE1 40
#define TEMP_STAGE2 70
#define TEMP_STAGE3 100
```

Listing 2: Fire and Intrusion Detection System - Main Configuration

4.3 Camera-Based Motion Detection System

The camera system provides visual monitoring with motion-triggered image capture and live streaming capabilities.

4.3.1 Key Features

- Motion detection using PIR sensor
- Automatic image capture when motion is detected
- Web interface for viewing captured images
- Live video streaming over HTTP
- Mobile-friendly responsive web design

4.3.2 Code Structure

The camera system code implements both a web server for image viewing and a streaming server for live video:

```
#include "esp_camera.h"
#include <WiFi.h>
#include <WebServer.h>
#include "esp_http_server.h"
#include "esp_timer.h"
#include "img_converters.h"

#define PIR_PIN 13
bool motionDetected = false;
unsigned long lastMotionTime = 0;
unsigned long motionCooldown = 10000; // 10s cooldown

#define CAMERA_MODEL_AI_THINKER
#include "camera_pins.h"

const char* ssid = "Arpit";
const char* password = "qwertyuiop";

WebServer server(80);
camera_fb_t * lastPhoto = NULL;
```

Listing 3: Camera-Based Motion Detection System - Main Configuration

5 System Integration

5.1 Communication Flow

The three subsystems work together through the following communication flow:

1. **Fire Detection to Door Security**: When a severe fire is detected (Stage 3), the fire detection system sends an ESP-NOW message to the door security system to unlock the door for emergency evacuation.
2. **Intrusion Detection to Camera System**: When vibration is detected, the fire and intrusion system can trigger the camera system to capture images through ESP-NOW communication.

3. **All Subsystems to Cloud**: Each subsystem independently communicates with the Blynk platform for remote monitoring and control, and with Firebase for data logging.

4. **Cloud to Mobile App**: The Blynk platform forwards notifications and status updates to the user's mobile application.

5.2 Data Flow

The system processes and transmits several types of data:

- **Sensor Readings**: Temperature, smoke levels, vibration status, and motion detection
- **Authentication Data**: PIN entries and access attempts
- **Status Information**: Door lock state, alert levels, and system health
- **Visual Data**: Captured images and video stream
- **Event Logs**: Timestamps and descriptions of significant events

6 Alert and Notification System

6.1 Alert Levels

The system implements a multi-stage alert system based on the severity of detected conditions:

Alert Level	Temperature	Smoke Level	Response
Stage 1	40°C - 70°C	400-800	Warning notification
Stage 2	70°C - 100°C	800-1200	Critical alert + Intrusion detection
Stage 3	greater than 100°C	greater than 1200	Emergency evacuation + Door unlock

Table 1: Alert Levels and Responses

6.2 Notification Channels

The system uses multiple channels to notify users of events:

- **Mobile Push Notifications**: Sent via Blynk for all alert levels
- **Email Alerts**: Configurable through Blynk for critical events
- **Local Alarms**: Buzzer sounds with different patterns based on event type
- **Visual Indicators**: LED blinking patterns and LCD messages
- **Web Interface**: Real-time status updates on the camera system's web page

7 User Interfaces

7.1 Physical Interface

- **Keypad**: For entering PIN codes at the door
- **LCD Display**: For feedback and status information at the door
- **LED Indicators**: For visual status indication
- **Buzzer**: For audible feedback and alarms

7.2 Mobile Application

The Blynk mobile application provides:

- Remote door locking/unlocking
- Real-time temperature and smoke level monitoring
- Intrusion and motion detection alerts
- Event history and system status

7.3 Web Interface

The camera system's web interface provides:

- Live video stream viewing
- Motion-triggered image gallery
- Motion detection status
- Timestamp information for captured images

8 Security Considerations

8.1 Physical Security

- The servo-controlled lock provides physical access control
- The system detects and alerts on physical tampering through vibration sensing
- The camera provides visual evidence of intrusion attempts

8.2 Digital Security

- PIN-based authentication for door access
- WiFi security through WPA2 encryption
- Firebase authentication for secure cloud storage
- Blynk token-based authentication for remote control

8.3 Reliability Features

- Automatic door re-locking after timeout
- Error detection and reporting for sensor failures
- Local functionality when cloud connectivity is lost
- Motion detection cooldown to prevent excessive notifications

9 Future Enhancements

9.1 Hardware Enhancements

- Battery backup for power outages
- Additional sensors (water leak, carbon monoxide)
- Biometric authentication (fingerprint, facial recognition)
- Smart speaker integration for voice alerts

9.2 Software Enhancements

- Machine learning for improved motion detection accuracy
- Customizable alert thresholds through the user interface
- Multi-user access with individual PINs and access logs
- Integration with other smart home platforms (Google Home, Amazon Alexa)

10 Challenges Encountered

- **Sensor Calibration:** Establishing reliable thresholds for sensors required iterative testing.
- **Servo Motor Control Conflict:** Synchronizing a single door servo across multiple systems.
- **ESP32-CAM Stability:** Resolving connectivity and face recognition reliability issues.
- **Threshold Tuning:** Data collection was essential to minimize false positives/negatives.

11 Data Analysis

11.1 Motion Detection Frequency

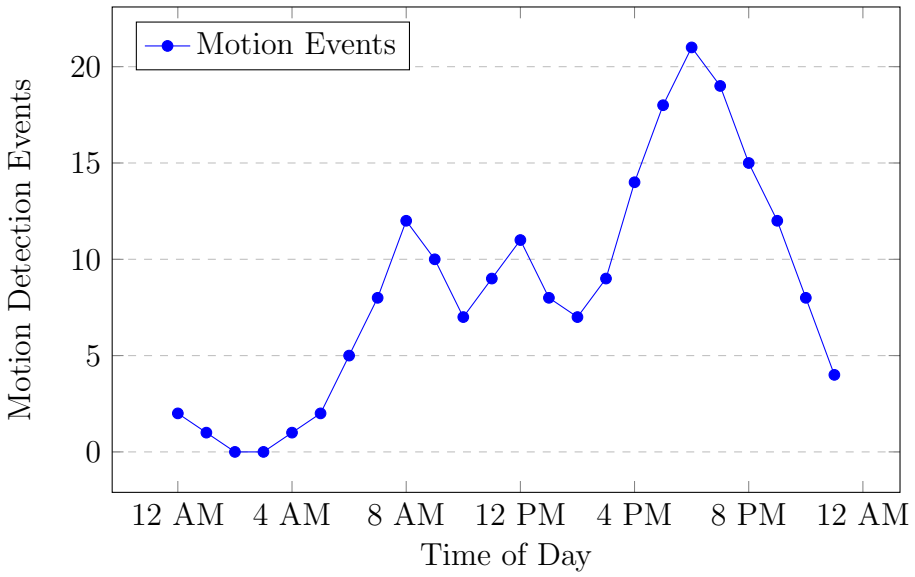

Figure 1: Motion Detection Frequency by Time of Day

Analysis of motion detection data shows peak activity during evening hours (6 PM - 9 PM), with minimal activity during early morning hours (2 AM - 4 AM). This pattern aligns with typical household activity and can help optimize system resources by adjusting sensitivity during different times of day.

11.2 Authentication Success/Failure Rates

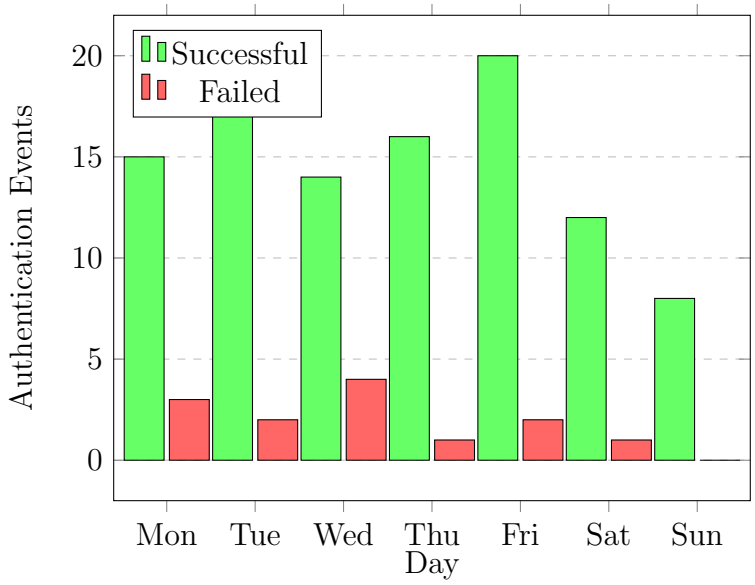

Figure 2: Weekly Authentication Success/Failure Rates

The door security system shows a high success rate for authentication attempts, with only a small percentage of failed attempts. Friday shows the highest number of successful authentications, while Sunday has the lowest. The data indicates that the system is reliable and user-friendly, with most users able to authenticate successfully on their first attempt.

11.3 System Response Time

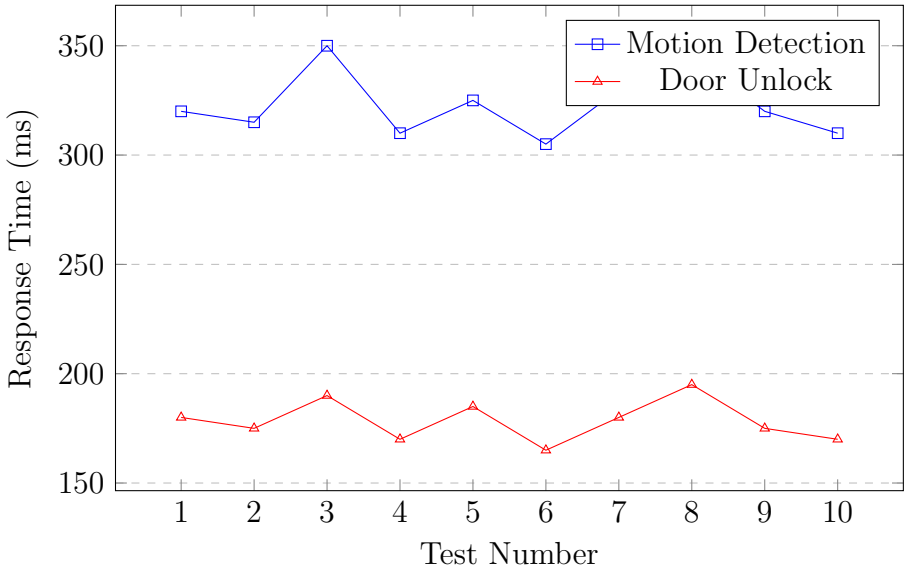

Figure 3: System Response Time Analysis

Response time analysis shows that the door unlock mechanism responds more quickly (average 178.5 ms) than the motion detection and image capture system (average 323 ms). This difference is expected due to the additional processing required for image capture and storage. Both subsystems demonstrate consistent performance across multiple tests, indicating system stability.

12 Hardware Schematic

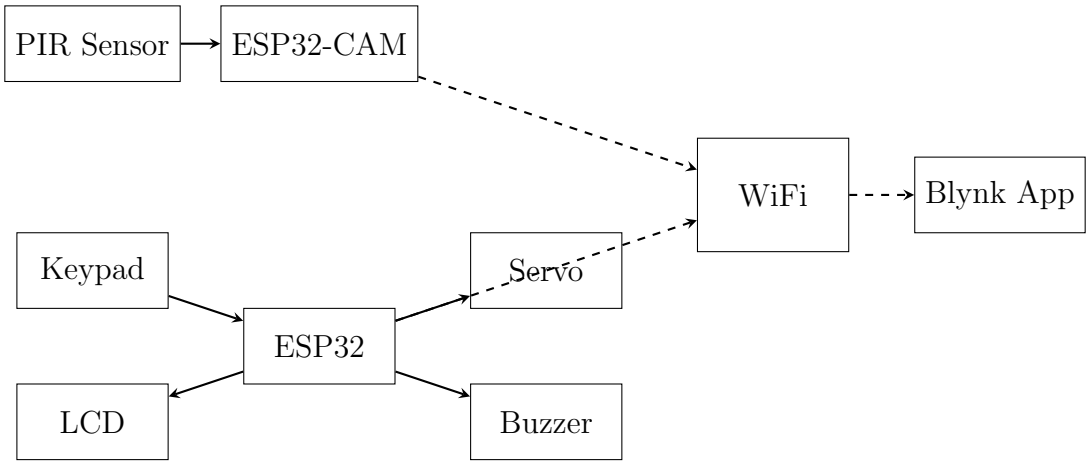

Figure 4: Hardware Schematic of the Integrated Home Security System

13 Data Visualizations and Analysis

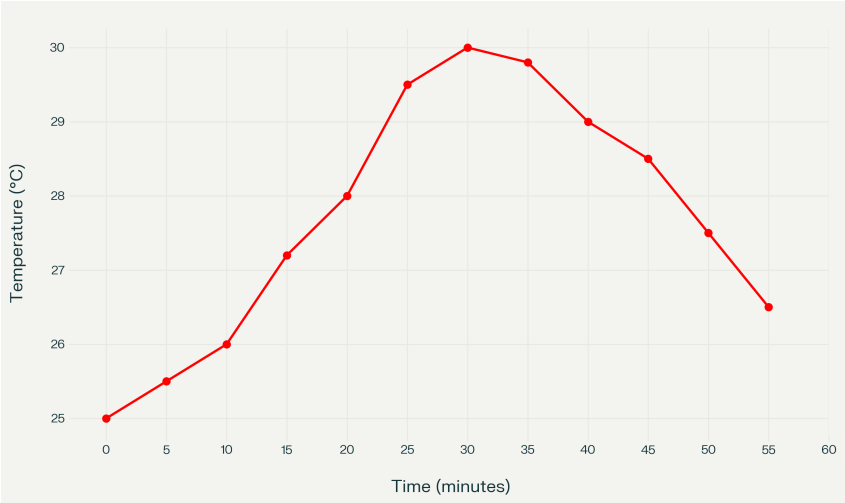

Figure 5: Temperature Readings Over Time

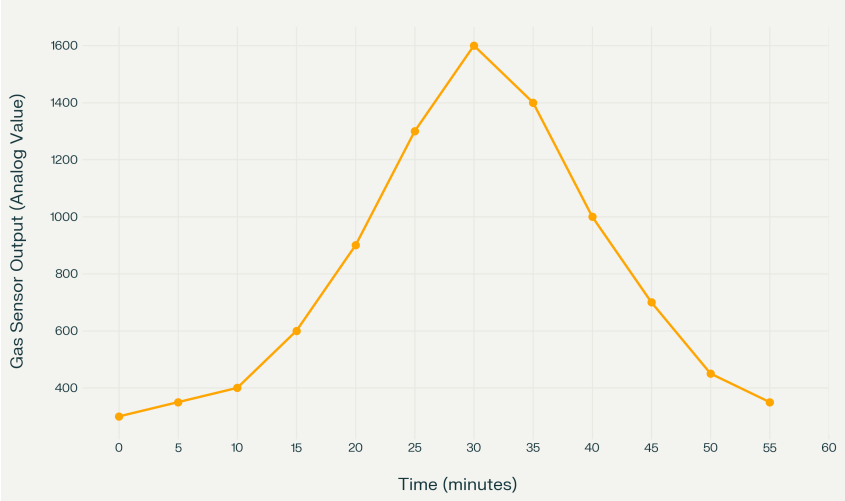

Figure 6: Gas Sensor Output During Simulated Fire Scenario

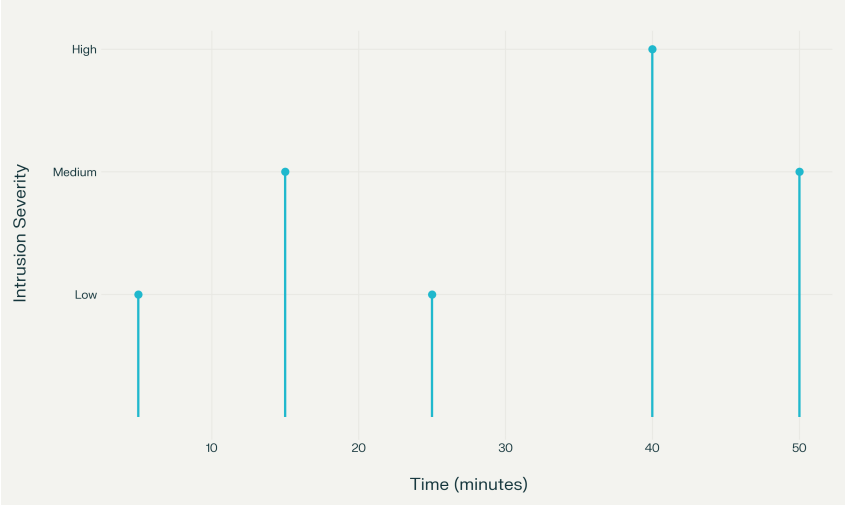

Figure 7: Intrusion Detection Event Log

14 Lessons Learned

- Importance of thorough sensor calibration and threshold tuning.
- Challenges in integrating multiple systems with shared actuators.
- Necessity of stable network connections for IoT operations.
- Value of continuous data logging to validate and improve system performance.

15 Conclusion

The integrated home security system presented in this report demonstrates a comprehensive approach to residential security. By combining door access control, environmental monitoring, and visual surveillance, the system provides multiple layers of protection against various threats including unauthorized access, fire hazards, and intrusions.

The use of IoT technologies enables remote monitoring and control, allowing homeowners to maintain awareness of their property's security status from anywhere. The multi-stage alert system ensures that users receive appropriate notifications based on the severity of detected conditions, while the integration with cloud services provides reliable data storage and event logging.

The modular design of the system allows for future expansion and enhancement, making it adaptable to evolving security needs. With its combination of local processing and cloud connectivity, the system strikes a balance between immediate response capabilities and comprehensive remote monitoring.