Smart Home

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Introduction

This project integrates three critical smart home systems into a unified Arduino-based controller:

1. **Home Security and Fire Detection System**: Monitors for unauthorized entry and fire hazards, with controlled door locking mechanisms and alarm capabilities.
2. **Rainwater Harvesting System**: Automatically collects rainwater when rain is detected and manages tank capacity.
3. **Motion-Activated Smart Lighting**: Intelligently controls lighting based on motion detection.

The integration allows these systems to work together seamlessly while sharing hardware resources and providing centralized monitoring through a serial interface.

Motivation

The motivation for this project stems from several factors:

- **Resource Efficiency**: Combining multiple home management systems on a single microcontroller reduces hardware costs and power consumption.
- **Safety and Security**: Creating an integrated approach to home safety that addresses multiple threats simultaneously (intrusion, fire) while providing emergency responses.
- **Sustainability**: Implementing rainwater harvesting to promote environmental conservation and reduce water consumption.
- **Energy Conservation**: Using motion detection for lighting control to minimize electricity usage.

Innovation/Uniqueness

The project stands out in several ways:

1. **Integrated Approach**: Unlike most DIY solutions that focus on a single aspect of home automation, this system combines security, safety and resource management in one circuit.
2. **Emergency Intelligence**: The system features cross-functional emergency protocols, such as automatically unlocking doors when a fire is detected.

3. **Debounced Sensing**: Implements sophisticated sensor debouncing techniques to prevent false alarms from ultrasonic and IR sensors.
4. **Password Protection**: Incorporates a code verification system with multiple authorized users.
5. **Graceful Motion**: Servo motors move gradually rather than abruptly, extending component life and providing visual feedback.
6. **Non-Blocking Design**: The entire system operates without blocking delays, allowing all systems to run concurrently.
7. **Adaptive Calibration**: The rainwater sensor uses adaptive thresholds to accommodate different environmental conditions.

Hardware Requirements

Security and Fire Detection System

- Arduino board (e.g., Arduino Uno or Mega)
- Ultrasonic distance sensor (HC-SR04)
- IR motion sensor
- Flame sensor
- Piezo buzzer
- Servo motor (for door lock)
- Red and green LEDs
- Resistors for LEDs (220Ω)

Rainwater Harvesting System

- Rain sensor (analog)
- Water level sensor
- Servo motor (for valve control)
- Resistors for pull-up (if needed)

Smart Lighting System

- Additional ultrasonic sensor (HC-SR04)
- Blue LED
- Power supply for lights

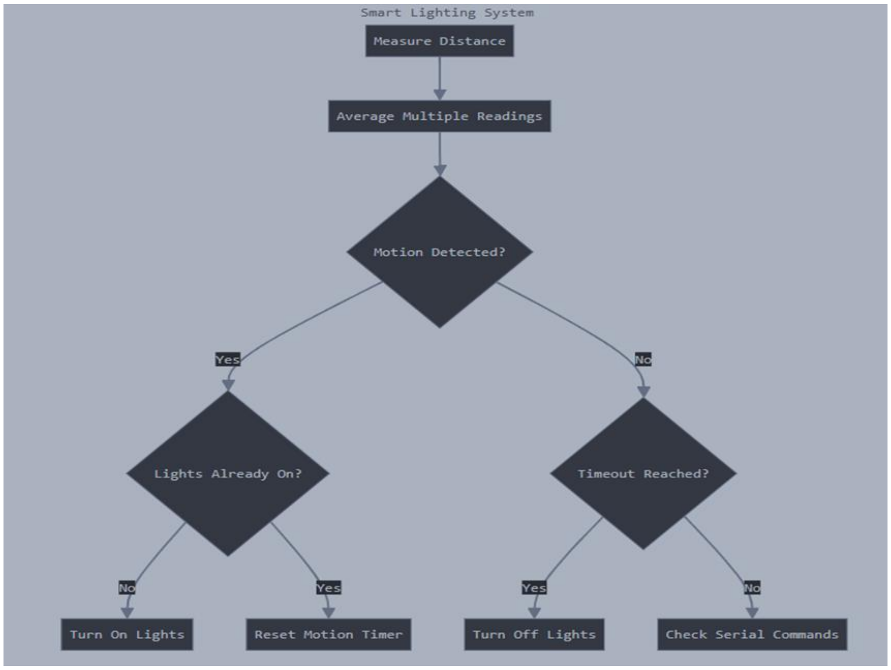
Miscellaneous

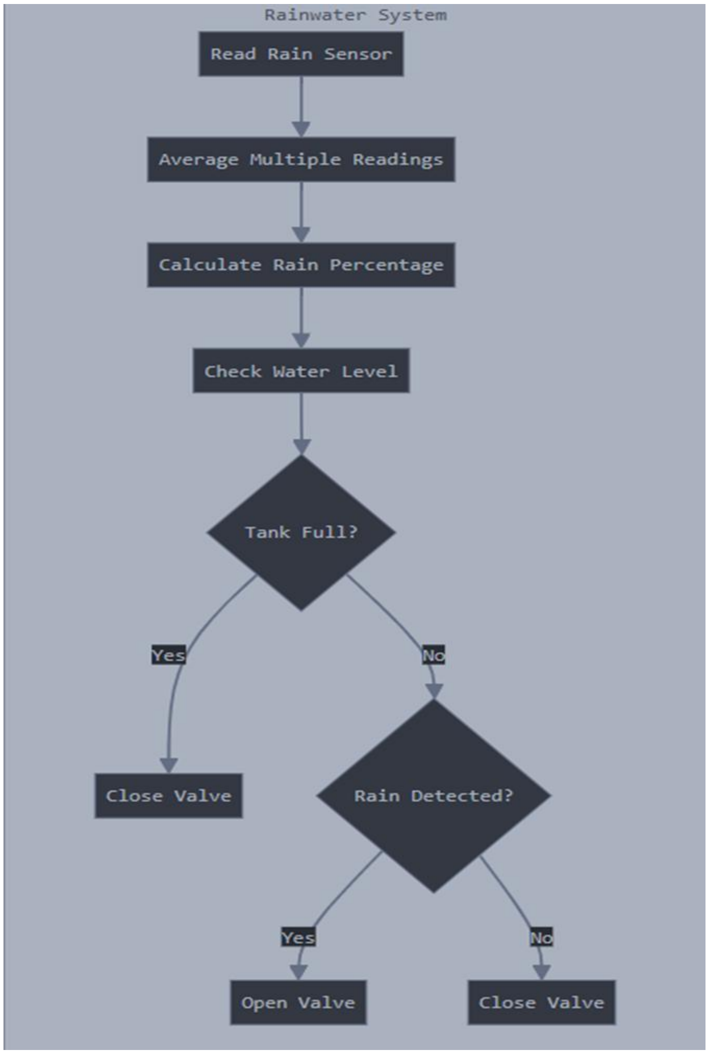
- Breadboard and jumper wires
- Power supply for Arduino
- Serial communication interface (USB or wireless)

Component Name	Quantity
Arduino Board (e.g., Uno)	**1**
Ultrasonic Sensor	**2**
IR Sensor	**1**
Buzzer	**1**
Servo Motor	**2**
LED (Red)	**1**
LED (Green)	**1**
LED (Blue)	**1**
Flame Sensor (Digital)	**1**
Rain Sensor (Analog)	**1**
Water Level Sensor	**1**
Breadboard	**1**

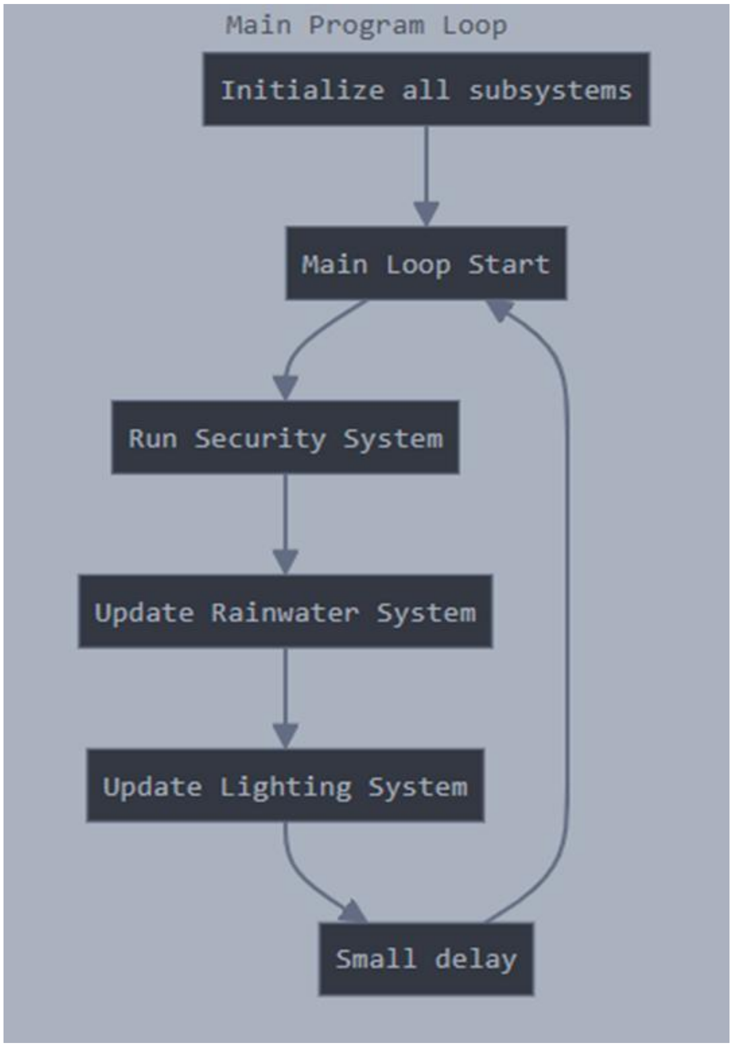
Flowcharts

Smart Lighting System

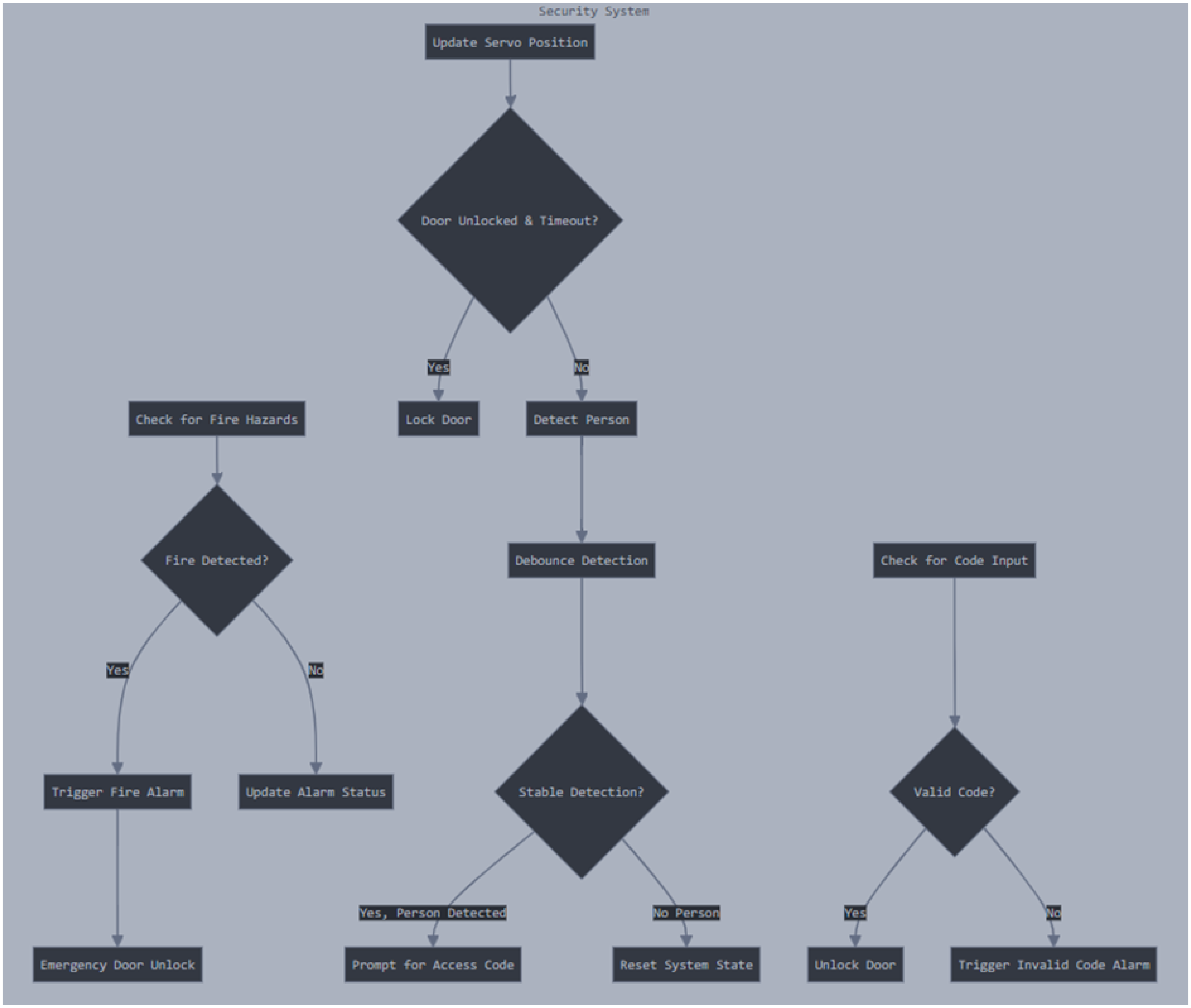




Rainwater Harvesting System

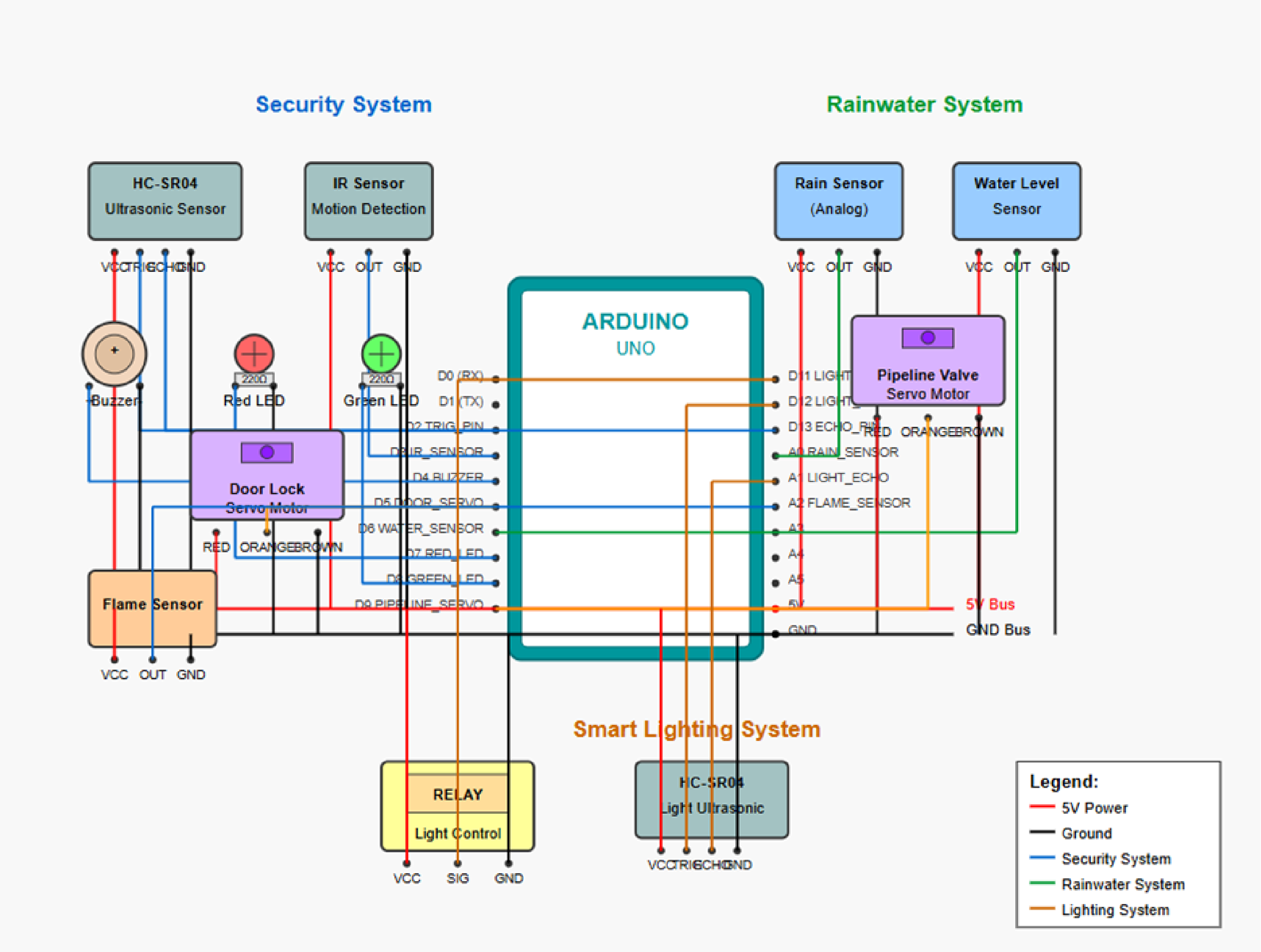


Main Program Loop



Security System

Circuit Diagram



Code Details

The code is organized into three main subsystems that share the Arduino's resources:

1. Security System: Handles intrusion detection, fire detection, and door locking mechanisms.
2. Rainwater System: Manages rain detection and water valve control.
3. Smart Lighting System: Controls lighting based on motion detection.

Each system has its own initialization function, update function, and dedicated set of pins. The systems operate independently but can influence each other, such as when the fire detection system triggers the emergency door unlock mechanism. Code has following functions:

1. Security System Functions

- initializeSecuritySystem(): Sets up pins, servo, and initial states for the security system
- detectIntrusion(): Uses ultrasonic and IR sensors to detect if someone is near the door
- promptForCode(): Requests an access code when a person is detected
- verifyAccessCode(): Checks if entered code matches authorized codes

- unlockDoor(): Opens the door when access is granted
- lockDoor(): Re-locks the door after timeout or on command
- updateServoPosition(): Gradually moves the door lock servo to target position
- resetAwaitingCode(): Cancels code request if no person is detected anymore
- triggerInvalidCodeAlarm(): Activates alarm when incorrect code is entered
- doubleBeep(): Produces notification sound for various security events
- runSecuritySystem(): Main function that coordinates security operations

2. Fire Detection System Functions

- detectFireHazard(): Checks flame sensor for fire detection
- triggerFireAlarm(): Activates alarm and emergency procedures when fire is detected
- updateFireAlarm(): Manages ongoing fire alarm state and responses
- resetFireAlarm(): Turns off alarm when fire is no longer detected
- emergencyUnlock(): Automatically unlocks door during fire emergency

3. Rainwater Harvesting System Functions

- initializeRainwaterSystem(): Sets up pins and servo for rainwater system
- updateRainwaterSystem(): Checks rain sensor and water tank level to control valve

4. Smart Lighting System Functions

- initializeLightingSystem(): Sets up pins for motion-activated lighting
- updateLighting(): Detects motion and controls lights based on presence

Each subsystem works independently but is integrated into the main program flow, with setup() initializing all systems and loop() running them continuously.

```
#include <Servo.h>

// Pin Definitions - Security System
const int ULTRASONIC_TRIG_PIN = 2;
const int ULTRASONIC_ECHO_PIN = 13;
const int IR_SENSOR_PIN = 3;
const int BUZZER_PIN = 4;
const int DOOR_LOCK_SERVO_PIN = 5;
const int LED_RED_PIN = 7;
const int LED_GREEN_PIN = 8;
const int FLAME_SENSOR_PIN = A2;  // Flame sensor digital pin

// Fire detection parameters
const int FLAME_THRESHOLD = LOW;  // Flame sensor outputs LOW when flame detected

// Distance threshold for ultrasonic sensors (in cm)
const int DISTANCE_THRESHOLD = 100;

// Pin Definitions - Rainwater System
#define RAIN_SENSOR A0
```

```
#define WATER_SENSOR 6
#define PIPELINE_SERVO_PIN 9

// Pin Definitions - Smart Lighting System
const int LIGHT_CONTROL_PIN = 11;
const int LIGHT_ULTRASONIC_TRIG_PIN = 12;
const int LIGHT_ULTRASONIC_ECHO_PIN = A1;

// Constants
const int RAIN_THRESHOLD = 700;  // Rain threshold
const int SERVO_OPEN = 90;
const int SERVO_CLOSED = 0;
const int RAIN_CHECK_INTERVAL = 2000;
const int LIGHT_CHECK_INTERVAL = 2000;
const unsigned long DOOR_OPEN_DURATION = 5000;
const unsigned long FIRE_CHECK_INTERVAL = 5000;
const unsigned long SERVO_MOVE_INTERVAL = 20;
const unsigned long MOTION_CHECK_INTERVAL = 1000;
const unsigned long DEBOUNCE_DELAY = 500;     // Debounce delay for ultrasonic
detection

// Servo objects
Servo doorLockServo;
Servo pipelineValve;

// Timing and State Variables
unsigned long doorUnlockTime = 0;
unsigned long lastFireCheckTime = 0;
unsigned long lastServoMoveTime = 0;
unsigned long lastRainCheckTime = 0;
unsigned long lastLightCheckTime = 0;
unsigned long lastMotionCheckTime = 0;
unsigned long lastDetectionChange = 0;      // For debouncing
unsigned long lastMotionTime = 0;

bool isDoorUnlocked = false;
bool isFireAlarmActive = false;
bool isAwaitingCode = false;
bool isInvalidCodeAlarm = false;
int currentServoPosition = 0;
int targetServoPosition = 0;
bool lastIntrusionState = false;
bool stableIntrusionState = false;          // Debounced intrusion state

// Rain System Variables
String valveStatus = "CLOSED";

// Smart Lighting Variables
bool isLightOn = false;
```

```
// Valid access codes
const String validCodes[3] = {
  "1234",  // Family Member 1
  "5678",  // Family Member 2
  "9012"   // Family Member 3
};

// Function declarations
bool detectIntrusion();
bool detectFireHazard();
void updateFireAlarm();
void resetFireAlarm();
void triggerFireAlarm();
void emergencyUnlock();
bool verifyAccessCode();
void unlockDoor();
void lockDoor();
void updateServoPosition();
void promptForCode();
void resetAwaitingCode();
void triggerInvalidCodeAlarm();
void runSecuritySystem();
void initializeSecuritySystem();
void initializeRainwaterSystem();
void updateRainwaterSystem();
void initializeLightingSystem();
void updateLighting();
void doubleBeep();

// Security System Initialization Function
void initializeSecuritySystem() {
  pinMode(ULTRASONIC_TRIG_PIN, OUTPUT);
  pinMode(ULTRASONIC_ECHO_PIN, INPUT);
  pinMode(IR_SENSOR_PIN, INPUT);
  pinMode(BUZZER_PIN, OUTPUT);
  pinMode(LED_RED_PIN, OUTPUT);
  pinMode(LED_GREEN_PIN, OUTPUT);
  pinMode(FLAME_SENSOR_PIN, INPUT);  // Initialize flame sensor pin (A2)

  digitalWrite(LED_RED_PIN, LOW);
  digitalWrite(LED_GREEN_PIN, LOW);
  digitalWrite(BUZZER_PIN, LOW);

  doorLockServo.attach(DOOR_LOCK_SERVO_PIN);
  doorLockServo.write(0);  // Initial locked position
  currentServoPosition = 0;
  targetServoPosition = 0;
  Serial.println("Security and Fire Detection System Initialized");
}

// Function to produce a double beep notification
void doubleBeep() {
  digitalWrite(BUZZER_PIN, HIGH);
  delay(200);
  digitalWrite(BUZZER_PIN, LOW);
  delay(200);
  digitalWrite(BUZZER_PIN, HIGH);
  delay(200);
  digitalWrite(BUZZER_PIN, LOW);
}

bool detectIntrusion() {
  // Ultrasonic distance measurement with averaging
  long duration, distance = 0;

  // Take multiple readings and average them for stability
  const int NUM_READINGS = 3;
  for (int i = 0; i < NUM_READINGS; i++) {
    // Clear the trigger pin
    digitalWrite(ULTRASONIC_TRIG_PIN, LOW);
    delayMicroseconds(2);

    // Send 10µs pulse to trigger
    digitalWrite(ULTRASONIC_TRIG_PIN, HIGH);
    delayMicroseconds(10);
    digitalWrite(ULTRASONIC_TRIG_PIN, LOW);

    // Measure the echo time and calculate distance
    duration = pulseIn(ULTRASONIC_ECHO_PIN, HIGH, 30000); // Timeout after 30ms

    // Check if we got a valid reading
    if (duration > 0) {
      distance += (duration / 2) / 29.1; // Convert to cm
    }

    // Small delay between readings
    delay(10);
  }

  // Calculate average distance
  distance = distance / NUM_READINGS;

  // Intrusion detected if object is closer than threshold and IR is triggered
  int irState = digitalRead(IR_SENSOR_PIN);

  // Print debug information periodically
  static unsigned long lastDebugPrint = 0;
  if (millis() - lastDebugPrint > 1000) {
    Serial.print("Distance: ");
    Serial.print(distance);
    Serial.print(" cm, IR State: ");
    Serial.println(irState == HIGH ? "ACTIVE" : "INACTIVE");
    lastDebugPrint = millis();
  }

  // Return intrusion state based on both sensors
  return (distance < DISTANCE_THRESHOLD && distance > 0 && irState == HIGH);
}

bool detectFireHazard() {
  // Read flame sensor state
  int flameState = digitalRead(FLAME_SENSOR_PIN);

  // Debug print every 2 seconds
  static unsigned long lastFlamePrint = 0;
  if (millis() - lastFlamePrint > 2000) {
    Serial.print("Flame Sensor State: ");
    Serial.println(flameState == LOW ? "FLAME DETECTED" : "NO FLAME");
    lastFlamePrint = millis();
  }

  // Return true if flame is detected (LOW signal)
  return (flameState == FLAME_THRESHOLD);
}

void triggerFireAlarm() {
  isFireAlarmActive = true;
  Serial.println("FIRE EMERGENCY! EVACUATE IMMEDIATELY!");

  // Turn on buzzer continuously for fire alarm
  digitalWrite(BUZZER_PIN, HIGH);
  digitalWrite(LED_RED_PIN, HIGH); // Keep red LED on for visual indication

  // Start emergency actions
  emergencyUnlock();
}

void updateFireAlarm() {
  if (isFireAlarmActive) {
    // Check flame sensor state
    int flameState = digitalRead(FLAME_SENSOR_PIN);

    // If no flame is detected, reset after a delay to avoid false negatives
    static unsigned long noFlameTime = 0;
    if (flameState != FLAME_THRESHOLD) {  // HIGH indicates no flame
```

```
      if (noFlameTime == 0) {
        noFlameTime = millis();
      } else if (millis() - noFlameTime > 10000) {  // 10 seconds of no flame
        resetFireAlarm();
        noFlameTime = 0;
        return;
      }
    } else {
      noFlameTime = 0;  // Reset timer if flame is detected again

      // Ensure buzzer stays on continuously during fire
      digitalWrite(BUZZER_PIN, HIGH);
      digitalWrite(LED_RED_PIN, HIGH); // Keep LED on

      // Print continuous fire alert periodically
      static unsigned long lastFirePrint = 0;
      if (millis() - lastFirePrint > 2000) {
        Serial.println("FIRE EMERGENCY! EVACUATE IMMEDIATELY!");
        Serial.print("Flame Sensor State: ");
        Serial.println(flameState == LOW ? "FLAME DETECTED" : "NO FLAME");
        lastFirePrint = millis();
      }
    }

    // Ensure door remains unlocked
    if (!isDoorUnlocked || currentServoPosition != 90) {
      emergencyUnlock(); // Keep door open if it was closed
    }
  }
}

void resetFireAlarm() {
  isFireAlarmActive = false;
  digitalWrite(BUZZER_PIN, LOW); // Stop the buzzer
  digitalWrite(LED_RED_PIN, LOW); // Turn off red LED
  Serial.println("Fire alarm reset. Fire no longer detected.");

  // Lock the door after fire is out
  if (isDoorUnlocked) {
    lockDoor();
  }
}

void emergencyUnlock() {
  // Automatically unlock door during fire emergency
  targetServoPosition = 90;  // Set unlock position as target
  Serial.println("Emergency Door Unlock Activated");
  isDoorUnlocked = true;
  doorUnlockTime = millis();
```

```
}

bool verifyAccessCode() {
  // Code Verification Process
  if (Serial.available() > 0) {
    String inputCode = Serial.readStringUntil('\n');
    inputCode.trim();  // Remove whitespace

    // For debugging
    Serial.print("Code entered: ");
    Serial.println(inputCode);

    // Check against valid codes
    for (int i = 0; i < 3; i++) {
      if (inputCode == validCodes[i]) {
        unlockDoor();
        isAwaitingCode = false;
        isInvalidCodeAlarm = false;
        digitalWrite(BUZZER_PIN, LOW);
        digitalWrite(LED_RED_PIN, LOW);
        return true;
      }
    }

    // Invalid code attempt
    Serial.println("Invalid Access Code!");
    if (!isInvalidCodeAlarm) {
      triggerInvalidCodeAlarm();
    }
  }
  return false;
}

void unlockDoor() {
  // Servo-based Door Unlocking Mechanism
  Serial.println("Access Granted! Door Unlocking...");

  // Visual Indication
  digitalWrite(LED_GREEN_PIN, HIGH);

  // Set target for servo to gradually move to unlock position
  targetServoPosition = 90;
  isDoorUnlocked = true;
  doorUnlockTime = millis();
}

void lockDoor() {
  // Re-lock Door gradually
  targetServoPosition = 0;  // Set target position to locked
  digitalWrite(LED_GREEN_PIN, LOW);
  isDoorUnlocked = false;

  Serial.println("Door Locking...");
}

void updateServoPosition() {
  // Gradually move servo toward target position
  if (currentServoPosition != targetServoPosition) {
    if (millis() - lastServoMoveTime >= SERVO_MOVE_INTERVAL) {
      // Move servo one degree at a time toward target
      if (currentServoPosition < targetServoPosition) {
        currentServoPosition++;
      } else {
        currentServoPosition--;
      }

      doorLockServo.write(currentServoPosition);
      lastServoMoveTime = millis();

      // Print when door is fully locked/unlocked
      if (currentServoPosition == 90) {
        Serial.println("Door Fully Unlocked");
      } else if (currentServoPosition == 0) {
        Serial.println("Door Fully Locked");
      }
    }
  }
}

void promptForCode() {
  isAwaitingCode = true;
  Serial.println("Person detected. Please enter access code:");

  // Play double beep notification
  doubleBeep();
}

void resetAwaitingCode() {
  // Reset the awaiting code state if no person detected
  if (isAwaitingCode && !stableIntrusionState && !isInvalidCodeAlarm &&
!isDoorUnlocked) {
    isAwaitingCode = false;
    Serial.println("No person detected, system reset");
  }
}

void triggerInvalidCodeAlarm() {
  // Turn on alarm for invalid code
  digitalWrite(BUZZER_PIN, HIGH);
  digitalWrite(LED_RED_PIN, HIGH);
  isInvalidCodeAlarm = true;

  Serial.println("INVALID CODE ALARM: Enter correct code to disable");
}

void runSecuritySystem() {
  // Check for Fire Hazards at Intervals
  if (millis() - lastFireCheckTime >= FIRE_CHECK_INTERVAL) {
    if (detectFireHazard()) {
      triggerFireAlarm();
    }
    lastFireCheckTime = millis();
  }

  // Update fire alarm (non-blocking)
  updateFireAlarm();

  // Update servo position (gradual movement)
  updateServoPosition();

  // Auto-lock door after timeout, but only if no fire is active
  if (isDoorUnlocked && currentServoPosition == 90 && !isFireAlarmActive &&
      (millis() - doorUnlockTime > DOOR_OPEN_DURATION)) {
    lockDoor();
  }

  // Main Security System Logic - Detect person and perform debouncing
  bool currentIntrusionState = detectIntrusion();

  // Debounce the intrusion detection to prevent oscillation
  if (currentIntrusionState != lastIntrusionState) {
    lastDetectionChange = millis();
  }

  // After the debounce period, consider the state stable
  if ((millis() - lastDetectionChange) > DEBOUNCE_DELAY) {
    if (currentIntrusionState != stableIntrusionState) {
      stableIntrusionState = currentIntrusionState;

      // Only prompt for code when a new stable intrusion is detected
      if (stableIntrusionState && !isAwaitingCode && !isDoorUnlocked) {
        promptForCode();
      }
    }
  }

  // Update last intrusion state for debounce comparison
  lastIntrusionState = currentIntrusionState;

  // Reset awaiting code if no person detected for a period
  if (millis() - lastMotionCheckTime >= MOTION_CHECK_INTERVAL) {
    resetAwaitingCode();
    lastMotionCheckTime = millis();
  }

  // Check for Authorized Access Code
  verifyAccessCode();
}

// Rainwater System Functions
void initializeRainwaterSystem() {
  // Set pin modes
  pinMode(RAIN_SENSOR, INPUT);
  pinMode(WATER_SENSOR, INPUT_PULLUP);  // Assuming active-high sensor

  // Attach and initialize servo
  pipelineValve.attach(PIPELINE_SERVO_PIN);
  pipelineValve.write(SERVO_CLOSED);    // Start with valve closed

  Serial.println("Rainwater Harvesting System Initialized");
  Serial.println("Rain (%) | Tank Full | Valve Status");
}

void updateRainwaterSystem() {
  if (millis() - lastRainCheckTime >= RAIN_CHECK_INTERVAL) {
    //averaging for more stable readings
    int rainTotal = 0;
    const int NUM_SAMPLES = 5;

    // Take multiple readings and average them
    for (int i = 0; i < NUM_SAMPLES; i++) {
      rainTotal += analogRead(RAIN_SENSOR);
      delay(10); // Small delay between readings
    }

    int rainValue = rainTotal / NUM_SAMPLES;
    int waterLevel = digitalRead(WATER_SENSOR);

    // Debug: Print raw sensor value
    Serial.print("Raw Rain Value: ");
    Serial.println(rainValue);

    // Adjusted mapping for rain sensor
    // Dry: ~650-1023 (0%), Wet: ~200-300 (100%)
    int rainPercentage = 0;
    if (rainValue <= 300) {
      rainPercentage = 100; // Very wet
    } else if (rainValue >= 650) {
      rainPercentage = 0;   // Very dry (adjusted for ~677 dry reading)
    } else {
      rainPercentage = map(rainValue, 650, 300, 0, 100); // Linear mapping
    }

    // Force low percentages to 0 to avoid false rain detection
    if (rainPercentage < 30) {
      rainPercentage = 0; // Increased threshold to ensure dry reads 0%
    }

    bool isTankFull = (waterLevel == HIGH); // Tank full when sensor is HIGH

    // Control logic
    if (isTankFull) {
      pipelineValve.write(SERVO_CLOSED);
      valveStatus = "CLOSED - TANK FULL";
    } else if (rainPercentage >= 30) {
      pipelineValve.write(SERVO_OPEN);
      valveStatus = "OPEN - RAIN DETECTED";
    } else {
      pipelineValve.write(SERVO_CLOSED);
      valveStatus = "CLOSED - NO RAIN";
    }

    // Print status periodically
    static unsigned long lastStatusPrint = 0;
    if (millis() - lastStatusPrint >= 5000) {
      Serial.print("RAIN: ");
      Serial.print(rainPercentage);
      Serial.print("% | TANK: ");
      Serial.print(isTankFull ? "Full" : "Not Full");
      Serial.print(" | VALVE: ");
      Serial.println(valveStatus);
      Serial.print("Water Level Sensor: ");
      Serial.println(waterLevel == HIGH ? "HIGH (Full)" : "LOW (Not Full)");

      lastStatusPrint = millis();
    }

    lastRainCheckTime = millis();
  }
}

// Smart Lighting Functions
void initializeLightingSystem() {
  // Configure pin modes
  pinMode(LIGHT_CONTROL_PIN, OUTPUT);
  pinMode(LIGHT_ULTRASONIC_TRIG_PIN, OUTPUT);
  pinMode(LIGHT_ULTRASONIC_ECHO_PIN, INPUT);

  // Initialize light as off
  digitalWrite(LIGHT_CONTROL_PIN, LOW);
  isLightOn = false;

  Serial.println("Smart Lighting System Initialized");
}

void updateLighting() {
  if (millis() - lastLightCheckTime >= LIGHT_CHECK_INTERVAL) {
    // Ultrasonic distance measurement with averaging
    long duration, distance = 0;
    int validReadings = 0;

    // Take a few readings for stability
    const int NUM_READINGS = 3;
    for (int i = 0; i < NUM_READINGS; i++) {
      digitalWrite(LIGHT_ULTRASONIC_TRIG_PIN, LOW);
      delayMicroseconds(2);

      digitalWrite(LIGHT_ULTRASONIC_TRIG_PIN, HIGH);
      delayMicroseconds(10);
      digitalWrite(LIGHT_ULTRASONIC_TRIG_PIN, LOW);

      duration = pulseIn(LIGHT_ULTRASONIC_ECHO_PIN, HIGH, 30000);

      // Only count valid readings
      if (duration > 0) {
        distance += (duration / 2) / 29.1;
        validReadings++;
      }

      delay(10);
    }

    // Calculate average distance (protect against zero valid readings)
    if (validReadings > 0) {
      distance = distance / validReadings;
    } else {
      distance = DISTANCE_THRESHOLD + 1; // Assume no motion if no valid readings
    }

    // Motion detection logic
    bool currentMotionState = (distance < DISTANCE_THRESHOLD && distance > 0);

    // Debug output
    static unsigned long lastDebugPrint = 0;
    if (millis() - lastDebugPrint >= 1000) {
      Serial.print("LIGHTING: Distance=");
      Serial.print(distance);
      Serial.print(" cm, Motion=");
      Serial.print(currentMotionState ? "DETECTED" : "NONE");
      Serial.print(", Light=");
      Serial.print(isLightOn ? "ON" : "OFF");
      Serial.print(", TimeSinceMotion=");
      Serial.println(millis() - lastMotionTime);
      lastDebugPrint = millis();
    }

    // Light control logic
    const unsigned long LIGHT_TIMEOUT = 5000; // 5 seconds timeout

    if (currentMotionState) {
      if (!isLightOn) {
        digitalWrite(LIGHT_CONTROL_PIN, HIGH);
        isLightOn = true;
        lastMotionTime = millis();
        Serial.println("LIGHTING: Motion detected - Lights ON");
      }
    }

    if (isLightOn && (millis() - lastMotionTime >= LIGHT_TIMEOUT)) {
      digitalWrite(LIGHT_CONTROL_PIN, LOW);
      isLightOn = false;
      Serial.println("LIGHTING: Timeout reached - Lights OFF");
    }

    // Serial command handler for testing
    if (Serial.available() > 0) {
      String command = Serial.readStringUntil('\n');
      command.trim();

      if (command == "lightoff") {
        digitalWrite(LIGHT_CONTROL_PIN, LOW);
        isLightOn = false;
        Serial.println("LIGHTING: Manual override - Lights OFF");
      } else if (command == "lighton") {
        digitalWrite(LIGHT_CONTROL_PIN, HIGH);
        isLightOn = true;
        lastMotionTime = millis();
        Serial.println("LIGHTING: Manual override - Lights ON");
      } else if (command == "resetmotion") {
        lastMotionTime = 0;
        Serial.println("LIGHTING: Motion timer reset to zero");
      }
    }
```

```
    lastLightCheckTime = millis();
  }
}

// Setup function to initialize all systems
void setup() {
  // Initialize serial communication
  Serial.begin(9600);
  while (!Serial) {
    ; // Wait for serial port to connect
  }

  delay(1000);  // Stabilize system
  Serial.println("Initializing Integrated Smart Home System...");

  // Initialize all subsystems
  initializeSecuritySystem();
  initializeRainwaterSystem();
  initializeLightingSystem();

  Serial.println("System initialization complete. Running...");
}

// Main loop function
void loop() {
  // Run all subsystems
  runSecuritySystem();
  updateRainwaterSystem();
  updateLighting();

  // Small delay to prevent CPU hogging
  delay(10);
}
```

Project Outcome

The integrated smart home system successfully achieved the following results:

1. **Unified Home Management**: Created a single system that handles security, safety, resource management, and convenience features.
2. **Reliable Detection**: The security system can detect intruders using multiple sensors with debouncing to minimize false alarms.
3. **Fire Safety**: The system can detect fire hazards and automatically unlock doors for emergency evacuation while activating alarms.
4. **Access Control**: Implemented a multi-user code verification system for authorized entry.

5. **Water Conservation**: Created an automated rainwater harvesting system that collects water when it rains and prevents overflow.
6. **Energy Efficiency**: Implemented motion-activated lighting that only operates when needed.
7. **Hardware Economy**: Achieved multiple home automation functions with minimal hardware through efficient integration.
8. **Non-Blocking Operation**: All systems operate concurrently without interfering with each other through proper timing management.

Individual Contributions

Security and Fire Detection Systems

- **Shefali Bishnoi (2301CS87):** Developed the security system with ultrasonic and IR sensor integration for intrusion detection. Implemented the access code verification system and door locking mechanism with servo control for authorized entry.
- **Juhi Sahni (2301CS88):** Created the fire detection system using flame sensors to monitor for fire hazards. Implemented emergency protocols including alarm triggering, automatic door unlocking during fire emergencies, and reset functionality when fire is no longer detected.

Environmental Control Systems

- **Saniya Prakash (2301CS49):** Designed the rainwater harvesting system with rain sensors and water level detection. Implemented automated valve control to direct rainwater collection based on rainfall intensity and storage tank capacity.
- **Manvitha Reddy (2301CS29):** Developed the smart lighting system using ultrasonic sensors for motion detection. Created energy-efficient lighting control with automatic timeout features for testing and operation.

Each subsystem functions independently while being integrated into a cohesive smart home automation solution. The code demonstrates effective teamwork through standardized timing mechanisms, shared hardware resources, and consistent debugging outputs.