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MECHATRONICS SYSTEM INTEGRATION

MINI PROJECT

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Abstract

The aim of this project was to build a functional system that incorporates as many aspects of Mechatronics System Integration as possible. The task was to build a washing machine using different sensors and actuators, which was successfully executed.

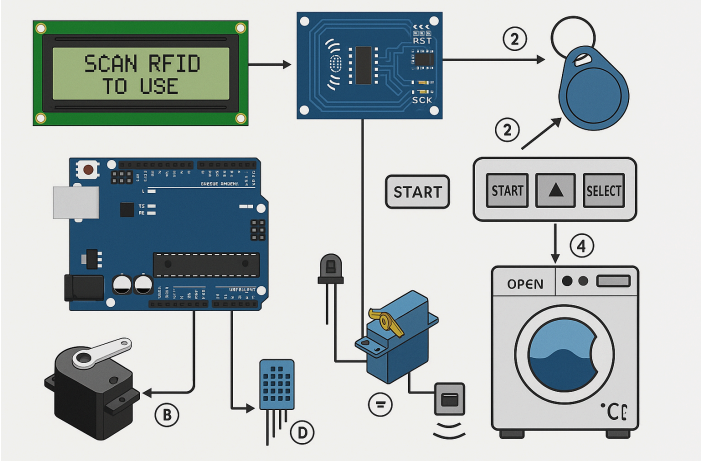
Introduction

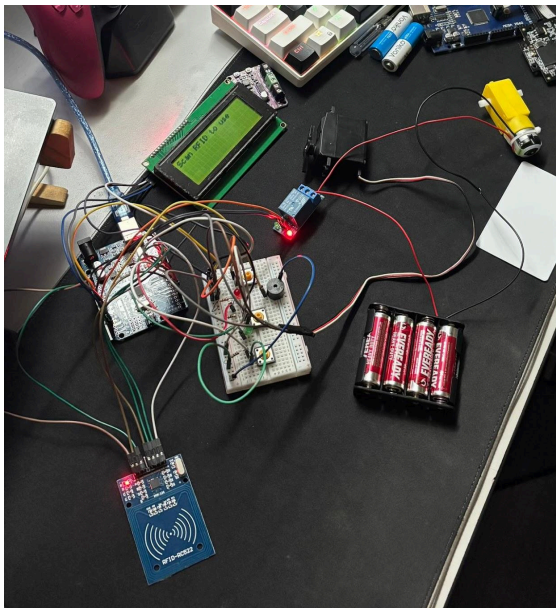
Washing machines are common devices found in almost every household. Some can only wash clothes, but some have a built-in dryer that allow them to automatically dry clothes once the clothes have been washed. Washing machines also come with many options that allow users to select the water level and the temperature of the water, among other things. Aside from that, public washing machines have even begun accepting cashless methods of payment. Keeping this in mind, we aimed to replicate most of these features when making our pseudo-washing machine, with a few additional features, too.

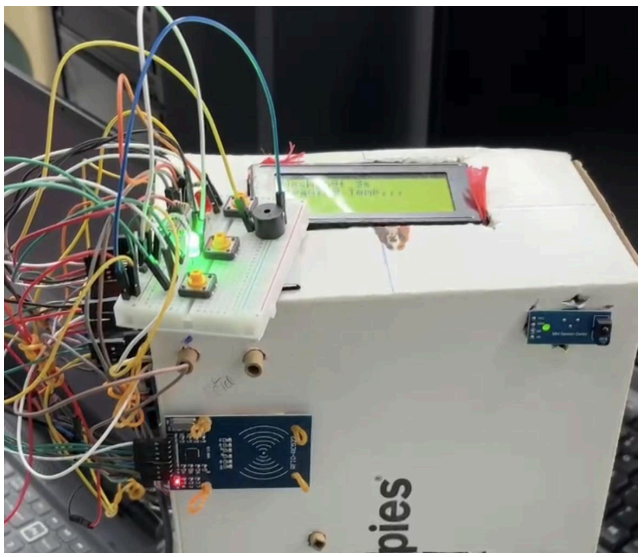
Materials And Equipment

1. Arduino Microcontroller
2. Jumper Wires
3. RFID Reader
4. DHT11
5. IR Sensor
6. DC Motor
7. Servo Motor
8. LCD
9. Push Buttons
10. LEDs
11. Double-A Batteries
12. Buzzer

Experimental Set-Up







Methodology

1. Motion Detection

- IR Sensor (PIR) detects motion.
- LCD shows: “Welcome!” → “Scan RFID to use”

2. RFID Authentication

- User scans RFID tag.
- If UID matches allowedUID, access is granted:
    - LCD: “Access Granted”
    - Door opens via servo motor.

3. Time Selection

- LCD shows: “Set Wash Time”
- User presses:
    - UP button: increases time.
    - SELECT button: confirms.
- Repeat for “Set Spin Time”.
- After setting both: LCD shows “Press START Btn”

4. Start Button Pressed

- Washing Phase:
    - Wash motor turns ON.
    - Water is controlled via relay.

    - LCD shows countdown and temperature (from DHT sensor).

- Spinning Phase:
    - Spin motor turns ON.
    - Relay controls motor/power.

5. Completion

- Buzzer plays melody
- Door unlocks
- LCD: “Cycle Complete!” → “Scan RFID to use”

System resets: waiting for the next user.

Coding parts :

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <SPI.h>
#include <MFRC522.h>
#include <Servo.h>
#include <DHT.h>

// LCD and RFID setup
LiquidCrystal_I2C lcd(0x27, 16, 2);
#define SS_PIN 10
#define RST_PIN 2
MFRC522 rfid(SS_PIN, RST_PIN);
byte allowedUID[4] = {0x6E, 0x66, 0xF5, 0x04}; // Replace with your UID

// I/O Pins
#define WASH_MOTOR 9
```

```
#define SPIN_MOTOR 3
#define START_BUTTON 4
#define UP_BUTTON 7
#define SELECT_BUTTON 6
#define SERVO_PIN 8
#define RELAY_PIN A0
#define BUZZER_PIN A1
#define DHT_PIN 5
#define IR_SENSOR_PIN A2 // Using analog pin as digital input

#define RELAY_ON LOW
#define RELAY_OFF HIGH

Servo doorServo;
DHT dht(DHT_PIN, DHT11);

int washTime = 5;
int spinTime = 5;
const unsigned long TIMEOUT_DURATION = 30000;
bool isAuthenticated = false;
bool welcomeShown = false;

void setup() {
  pinMode(WASH_MOTOR, OUTPUT);
  pinMode(SPIN_MOTOR, OUTPUT);
  pinMode(START_BUTTON, INPUT_PULLUP);
  pinMode(UP_BUTTON, INPUT_PULLUP);
  pinMode(SELECT_BUTTON, INPUT_PULLUP);
  pinMode(RELAY_PIN, OUTPUT);
  pinMode(BUZZER_PIN, OUTPUT);
  pinMode(IR_SENSOR_PIN, INPUT);

  digitalWrite(WASH_MOTOR, HIGH);
  digitalWrite(SPIN_MOTOR, HIGH);
```

```
  digitalWrite(RELAY_PIN, RELAY_OFF);

  lcd.init();
  lcd.backlight();

  Serial.begin(9600);
  SPI.begin();
  rfid.PCD_Init();
  dht.begin();

  doorServo.attach(SERVO_PIN);
  openDoor();
}

void loop() {
  // IR Sensor: Show Welcome once on motion
  if (!isAuthenticated && !welcomeShown) {
    if (digitalRead(IR_SENSOR_PIN) == LOW) {
      lcd.clear();
      lcd.setCursor(0, 0);
      lcd.print("   Welcome!   ");
      delay(1500);
      lcd.clear();
      lcd.print("Scan RFID to use");
      welcomeShown = true;
    }
  }

  if (!isAuthenticated) {
    if (checkRFID()) {
      isAuthenticated = true;
      lcd.clear();
      lcd.print("Access Granted");
      openDoor();
```

```
    delay(2000);

    if (!selectTime()) {
      lcd.clear();
      lcd.print("Timeout Reset");
      delay(1500);
      lcd.clear();
      welcomeShown = false;
      lcd.print("Scan RFID to use");
      isAuthenticated = false;
      return;
    }

    closeDoor();
    delay(1000);
  }
  return;
}

if (digitalRead(START_BUTTON) == LOW) {
  // Washing Phase
  tone(BUZZER_PIN, 1000, 200);
  digitalWrite(WASH_MOTOR, LOW);
  digitalWrite(SPIN_MOTOR, HIGH);
  digitalWrite(RELAY_PIN, RELAY_ON);
  countdownPhase("Washing", washTime);
  digitalWrite(RELAY_PIN, RELAY_OFF);
  digitalWrite(WASH_MOTOR, HIGH);
  delay(1000);

  // Spinning Phase
  tone(BUZZER_PIN, 1200, 200);
  digitalWrite(SPIN_MOTOR, LOW);
  digitalWrite(RELAY_PIN, RELAY_ON);
```

```
    countdownPhase("Spinning", spinTime);
    digitalWrite(RELAY_PIN, RELAY_OFF);
    digitalWrite(SPIN_MOTOR, HIGH);

    // Completion
    playMelody();
    openDoor();
    lcd.clear();
    lcd.print("Cycle Complete!");
    delay(3000);
    lcd.clear();
    lcd.print("Scan RFID to use");
    isAuthenticated = false;
    welcomeShown = false;
    washTime = 5;
    spinTime = 5;
  }
}

bool checkRFID() {
  if (!rfid.PICC_IsNewCardPresent() || !rfid.PICC_ReadCardSerial()) return false;

  if (rfid.uid.size != 4) {
    rfid.PICC_HaltA();
    return false;
  }

  for (byte i = 0; i < 4; i++) {
    if (rfid.uid.uidByte[i] != allowedUID[i]) {
      rfid.PICC_HaltA();
      return false;
    }
  }
  rfid.PICC_HaltA();
```

```
  return true;
}

bool selectTime() {
  const int defaultWash = 5;
  const int defaultSpin = 5;

  washTime = defaultWash;
  spinTime = defaultSpin;

  int* times[] = { &washTime, &spinTime };
  const char* labels[] = { "Set Wash Time", "Set Spin Time" };

  for (int i = 0; i < 2; i++) {
    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print(labels[i]);
    lcd.setCursor(0, 1);
    lcd.print(*times[i]); lcd.print(" sec");

    unsigned long startTime = millis();
    while (true) {
      if (millis() - startTime > TIMEOUT_DURATION) return false;
      if (digitalRead(UP_BUTTON) == LOW) {
        *times[i] += 1;
        if (*times[i] > 60) *times[i] = 1;
        lcd.setCursor(0, 1);
        lcd.print("                ");
        lcd.setCursor(0, 1);
        lcd.print(*times[i]); lcd.print(" sec");
        delay(200);
        startTime = millis();
      }
      if (digitalRead(SELECT_BUTTON) == LOW) {
```

```
        delay(300);
        break;
      }
    }
  }
  lcd.clear();
  lcd.print("Press START Btn");
  return true;
}

void countdownPhase(String title, int seconds) {
  for (int i = seconds; i >= 0; i--) {
    float temp = dht.readTemperature();
    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print(title); lcd.print(": "); lcd.print(i); lcd.print("s");
    lcd.setCursor(0, 1);
    if (!isnan(temp)) {
      lcd.print("Temp:"); lcd.print(temp, 1); lcd.print((char)223); lcd.print("C");
    } else {
      lcd.print("Reading Temp...");
    }
    delay(1000);
  }
  lcd.clear();
}

void openDoor() {
  doorServo.write(0);
  delay(500);
}

void closeDoor() {
  doorServo.write(90);
```

```
  delay(500);
}

void playMelody() {
  int melody[] = {262, 294, 330, 392, 523};
  for (int i = 0; i < 5; i++) {
    tone(BUZZER_PIN, melody[i], 200);
    delay(250);
  }
  noTone(BUZZER_PIN);
}
```

Discussion

The RFID-controlled smart washing machine project was successfully developed and implemented using an Arduino Uno, an MFRC522 RFID reader, and multiple sensors and actuators. All the necessary libraries, including `MFRC522.h`, were installed correctly, and the RFID system was able to recognize and authenticate pre-programmed UID tags with no major issues. Once authenticated, users were prompted via an LCD display to select washing and spinning times using push buttons. The setup also included a motion sensor that triggered a welcome message when someone approached the machine, creating a more interactive experience.

After time selection, the washing cycle began with the activation of the wash motor, followed by the spin motor, both controlled through relay switching. During operation, a DHT11 sensor continuously displayed the internal temperature, enhancing the system's realism. A servo motor was used to simulate an automatic door lock, securing the machine during operation and unlocking it after completion. A buzzer played a short melody to notify users once the cycle was finished. All hardware components—RFID, motors, servo, sensors, LCD, and buzzer—worked together smoothly, and no critical errors occurred throughout the experiment.

Overall, the project was successful. It met all the intended objectives, including user authentication, cycle customization, safety control, and feedback systems. The integration of both hardware and software was well-coordinated, and the result was a fully functional prototype of a smart washing machine system. The project demonstrated effective use of embedded systems and sensor-based automation.

Conclusion

In conclusion, the RFID-controlled washing machine system was successfully implemented. The RFID module was able to accurately identify the authorized tag, granting access to the system. Users could then set their preferred washing and spinning durations using the button interface. All components—including the LCD, buttons, servo motor, and relays—functioned as expected without any critical errors. The integration of motion sensing for user interaction and real-time temperature monitoring added practical value to the system.

To summarize, the experiment achieved its objective of creating a fully functional, interactive washing machine prototype. The system successfully guided the user from authentication through to cycle completion, providing clear feedback via the display and buzzer. The servo lock mechanism worked in sync with the wash cycle, ensuring a safety feature was in place. All expected outcomes were met, and the components operated in harmony throughout the process. Overall, the project demonstrated the effective application of embedded system design and sensor integration.

Recommendation

Overall, this project was a success with minimal disruption. However, while the outcome met the goal of the task, the project itself turned out to be too simple. It would have been better if more features had been added, such as a mini-music player or a screen to watch videos on.

References

- Rfid: https://randomnerdtutorials.com/security-access-using-mfrc522-rfid-reader-with-arduino/ How To Mechatronics – I2C LCD with Arduino
- LCD- https://howtomechatronics.com/tutorials/arduino/arduino-lcd-tutorial/
- DHT11 - https://arduinogetstarted.com/tutorials/arduino-dht11

Acknowledgement

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Student Declaration Form

This is to certify that we are responsible for the work submitted in this report, that **the original work** is our own except as specified in the references and acknowledgement, and that the original work contained herein have not been untaken or done by unspecified sources or persons.

We hereby certify that this report has **not been done by only one individual** and **all of us have contributed to the report**. The length of contribution to the reports by each individual is noted within this certificate.

We also hereby certify that we have **read** and **understand** the content of the total report and that no further improvement on the reports is needed from any of the individual contributors to the report.

We therefore, agree unanimously that this report shall be submitted for **marking** and this **final printed report** has been **verified by us**.

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Contribution : Discussion, Conclusion, Methodology		

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