LAB REPORT 4b :

SERIAL AND USB INTERFACING WITH MICROCONTROLLER AND COMPUTER-BASED SYSTEM (2): SENSORS AND ACTUATORS)

GROUP 5

MCTA 3203

SEMESTER 1 2024/2025

MECHATRONICS SYSTEM INTEGRATION

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INTRODUCTION

Radio Frequency Identification (RFID) technology has been in the realm of identification and authentication for various applications of access control, inventory management, and asset tracking. The following laboratory experiment is about controlling an RFID card reader using Arduino and Python for the authentication of RFID cards to control a servo motor based on recognized user credentials. The RFID reader talks to the computer via USB HID communication to detect the proximity of a card and matching the obtained ID with the stored IDs. The system is further enhanced by giving visual indicators using LEDs, where the green LED shows successful authentication and the red LED shows an unauthorized access attempt. Also, in storing and managing UID data, there is a structured JSON format followed, hence offering a very flexible and scalable way of user management and access control settings. This project combines all these multiple elements such as data handling, servo motor control, and real-time interaction through LEDs to be an effective introduction to the applications of RFID in authentication systems and the basics of hardware interfacing with Arduino.

ABSTRACT

In this project, the objective is to create a simple Python- and Arduino-driven RFID authentication system that will drive a servo motor. An RFID card reader connected via USB authenticates RFID tags with UIDs previously registered. Then, based on the result from this process, either grants or denies access by running a servo motor. JSON data handling was implemented to make the data more structured and flexible, allowing any addition or change of registered UIDs easily. The following project is therefore a practical application of RFID technology in security systems and mainly concentrates on the integration of structured data handling, visual indication, and hardware control for expanded functionality and improved user-friendliness.

MATERIALS AND EQUIPMENT

- Arduino board
- RFID card reader with USB connectivity
- RFID tags or cards that can be used for authentication
- Servo Motor: A standard servo motor to control the angle
- Jumper wires
- Breadboard
- LEDs of various colours
- USB cables to connect the Arduino board and the RFID reader to your computer.
- Computer with Arduino IDE and Python installed
- Datasheets and Manuals: Make sure you have the datasheets or manuals for the RFID reader, servo motor, and any other components you are using. Most of them can be downloaded from the internet. Before starting the experiment, carefully read the documentation for each component and understand the electrical and mechanical requirements. Also, consider safety protocols and guidelines to ensure a safe working environment in the lab.
- Power Supply (optional): If the servo motor requires a power supply other than what the Arduino can provide, you'll need the appropriate power supply.
- Mounting Hardware (for the servo): If you want to mount the servo in a specific orientation or location, you might need screws, brackets, or other mounting hardware.

EXPERIMENTAL SETUP

```
   Arduino                          Servo Motor
+------------+                  +----------------+
|            |                  |                |
|     5V     |------------------| Power (Red)    |
|            |                  |                |
|     GND    |------------------| Ground (Brown) |
|            |                  |                |
|     D9     |------------------| Signal (Yellow)|
|            |                  |                |
+------------+                  +----------------+
```

METHODOLOGY

1. Hardware Setup

- Servo Motor Wiring:
  - Connect the servo motor's power wire to the 5V pin on the Arduino, ground to a GND pin, and signal wire to a PWM pin (e.g., pin 9).
  - Ensure a common ground connection between Arduino and the servo motor.
- RFID Reader Wiring:
  - Connect the RFID reader to the computer via USB for power and communication, using the USB HID protocol.

2. Software Programming and Execution

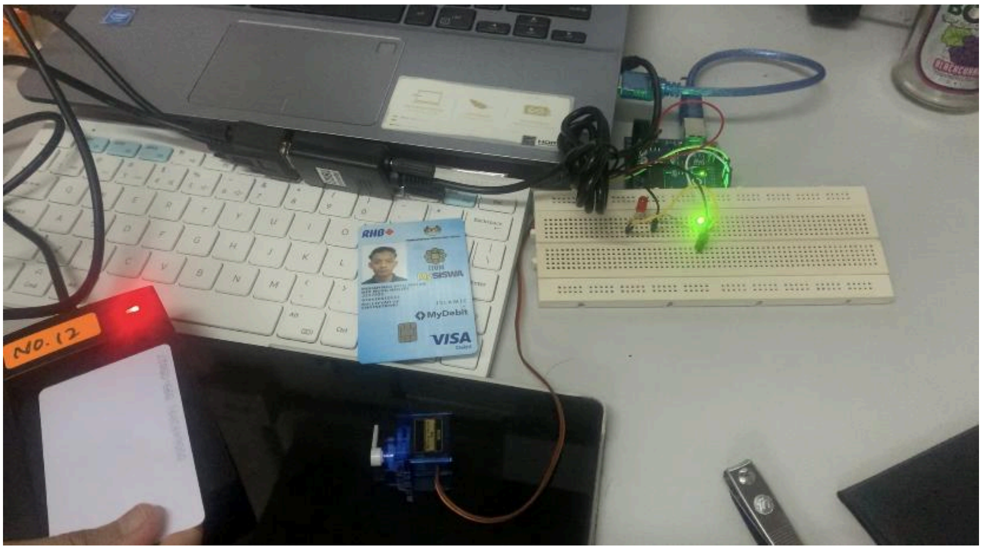
- Arduino Code Development:
  - Code was written in the Arduino IDE to initialize the servo on pin 9 and set a default angle position.
  - Listen for signals ("A" or "D") from Python to control the servo angle based on RFID card authentication.
  - Load and upload the code to the Arduino

- Running the Python Script
  - To execute the script, ensure that any necessary libraries, such as pyusbl are installed.
  - In Python script, the RFID reader using its vendor and product IDs will detect and read the RFID card data and match it to predefined, authorized card IDs.
  - A signal ('A' for access granted, 'D' for access denied) to the Arduino to adjust the servo position will be sent.
  - A green LED if the card is authorized or a red LED if unauthorized will be activated.

- Running the Experiment
    - Place RFID cards near the reader and observe the system’s response.
    - For authorized cards, the servo motor should adjust to a specific angle, and the green LED should illuminate.
    - For unauthorized cards, the red LED should illuminate, and the servo should reset to its default position.

- Additional Enhancements
    - Introduce visual indicators (LEDs) and JSON data handling in the code for structured data management.
    - Allow user-defined angle positioning for the servo through Python, providing more flexibility in the control mechanism.

RESULTS



Video Link:

https://github.com/GROUP5-MSI/WEEK-4_Serial-Communication/blob/main/Video%20W4%20Part%20B%20RFID%20demo.mov

Arduino code:

```
#include <MFRC522.h>
#include <Servo.h>

// Pin definitions
#define SERVO_PIN       12          // Servo control pin
#define GREEN_LED_PIN   6         // Green LED
#define RED_LED_PIN     7           // Red LED

Servo accessServo;                // Create servo instance

// Array of authorized cards
byte authorizedCards[][4] = {
  {0x33, 0x36, 0x87, 0x1A} // Card for granted and tag for decline (Not Here
Easier to code then making another function)
};

const int NUM_CARDS = sizeof(authorizedCards) / sizeof(authorizedCards[0]);

void setup() {
  Serial.begin(9600);
  SPI.begin();                   // Initialize SPI bus
  rfid.PCD_Init();               // Initialize RFID reader
```

```
  // Initialize servo
  accessServo.attach(SERVO_PIN);
  accessServo.write(0);             // Set initial position

  // Initialize LEDs
  pinMode(GREEN_LED_PIN, OUTPUT);
  pinMode(RED_LED_PIN, OUTPUT);

  Serial.println("System Ready");
}

void loop() {
  // Reset the loop if no new card is present
  if (!rfid.PICC_IsNewCardPresent() || !rfid.PICC_ReadCardSerial())
    return;

  // Check if card is authorized
  if (isAuthorizedCard(rfid.uid.uidByte)) {
    grantAccess();
  } else {
    denyAccess();
  }

  // Halt PICC and stop encryption
  rfid.PICC_HaltA();
  rfid.PCD_StopCrypto1();
}

bool isAuthorizedCard(byte *cardUID) {
  for (int i = 0; i < NUM_CARDS; i++) {
    if (compareUIDs(cardUID, authorizedCards[i])) {
      return true;
    }
  }
  return false;
}

bool compareUIDs(byte *uid1, byte *uid2) { //comparison algorithm
  for (int i = 0; i < 4; i++) {
    if (uid1[i] != uid2[i]) {
      return false;
    }
  }
  return true;
}

void grantAccess() {
  Serial.println("Access granted");
  digitalWrite(GREEN_LED_PIN, HIGH);
  digitalWrite(RED_LED_PIN, LOW);
```

```
  // Move servo to open position
  accessServo.write(90);
  delay(1000);                      // Keep open for 1 seconds

  // Return to closed position
  accessServo.write(0);
  digitalWrite(GREEN_LED_PIN, LOW);
}

void denyAccess() {
  Serial.println("Access denied");
  digitalWrite(RED_LED_PIN, HIGH);
  delay(1000);
  digitalWrite(RED_LED_PIN, LOW);
}
```

DISCUSSION

This project demonstrated two applications: gesture detection using the MPU6050 sensor and RFID-based access control using the MFRC522 module and a servo motor. By monitoring acceleration thresholds, the MPU6050 accelerometer and gyroscope may detect tilt gestures in both the forward and backward directions. By verifying that the system reliably detects and displays these motions on the serial monitor, video observations establish the technology's potential for simple gesture-based controls. Promising applications include robotics and other fields where straightforward movement-based controls could streamline interactions.

By indicating denial with a red LED for illegal attempts and triggering the servo motor to open for permitted access, the RFID-based access system consistently differentiated between approved and unauthorized cards. This performance demonstrates the system's ability to provide secure access management, which makes it suitable for settings like offices or labs that need restricted access. The actual and anticipated results differed in a few ways. Still, there were a few cases when minor misalignments or background vibrations led to missed detections or false positives. These results demonstrate how important it is to align and stabilize the MPU6050 to increase the accuracy of detection. Similar to this, even though the RFID technology worked as intended most of the time, occasional faults between the RFID card and scanner led to missed scans. These discrepancies suggest that further development is needed to provide dependable performance, especially in frequently used situations.

Sensor noise and power fluctuations can affect gesture detection, and the fixed sensitivity limit might not work well in some situations. Depending on the specific application, the MPU6050 calibration and threshold values could be changed to improve reliability. Errors about card orientation and reader interference were noted. Furthermore, variations in power had an impact on the servo motor's dependability. Scalability and responsiveness would be improved by integrating a more flexible permission mechanism, such as a dynamic database for permitted cards, and by including feedback for the servo's location.

Overall, the experiment's two components were limited but functional. Only two motions could be detected, and the system was susceptible to ambient shocks, which could lead to accidental detections. The servo's constant open/close duration limited its adaptability, while the RFID system's fixed list of permitted cards and lack of remote update options hampered its scalability. Overall, this experiment illustrated the fundamental concepts of gesture detection and safe access management, which, with a few tweaks, might find broader use in robotics and security systems.

CONCLUSION

The last analysis indicates that this was an effective experiment in proving an RFID-based authentication system implemented on the Arduino platform using the Python interface. The setup was able to distinguish between an authorized and an unauthorized card by reading RFID card UIDs with a reader connected via USB HID. Recognized UIDs turned the green LED on and activated the servo motor and unrecognized UIDs turned the red LED on. It also uses JSON data handling, making it very simple and flexible to store and manage registered UIDs for further expansion. The addition of user-controlled servo angle settings made the system more functional and versatile for applications requiring exact motor positioning. This experiment collectively shows a practical way of having RFID-based access control that incorporates data handling, visual indicators, and motor control to make the system responsive.

RECOMMENDATION

For the RFID-RC522 authentication system experiment, students can enhance the servo motor control by introducing acceleration profiles for smoother, more precise movements. Adding multiple authentication states with corresponding LED indicators would improve system feedback. Implementing a Python multithreading approach could allow simultaneous handling of RFID reading and servo control tasks. Conducting multiple test runs with varied RFID cards and servo motions would help fine-tune the system, boosting both its accuracy and reliability. These adjustments would make the experiment more efficient and reduce potential errors.

ACKNOWLEDGEMENTS

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STUDENT'S DECLARATION

Certificate of Originality and Authenticity

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 acknowledgment, and that the original work contained herein has 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, agreed unanimously that this report shall be submitted for **marking** and this **final printed report** has been **verified by us**.

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