MCTA 3203

MECHATRONIC SYSTEM INTEGRATION

SECTION 1

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LAB REPORT 4B:

SERIAL COMMUNICATION (RFID)

GROUP 2

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ABSTRACT

In this project, the goal is to develop a basic Python- and Arduino-powered system of RFID authentication, which will control a servo motor. A connected via-USB RFID card reader authenticates RFID tags with already registered UIDs. Subsequently, grants or denies access based on the output of this system by controlling a servo motor. Handling of JSON data was added in order to structure the data more effectively, to allow any registered UIDs addition or modification easily. The given project is therefore an implementation of RFID technology in security systems with main concern to integrate structured data handling, visual feedback, and hardware control for added functionality and improved user-friendliness.

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INTRODUCTION

In modern mechatronic systems, integrating sensors and actuators with microcontrollers via serial and USB communication is crucial for building responsive and intelligent applications. This lab focuses on implementing a real-time RFID-based authentication system using an Arduino microcontroller and a USB RFID card reader. The core objective is to demonstrate secure access control using RFID technology while controlling a servo motor based on authorized or unauthorized card detections.

The experiment leverages serial communication between the computer and Arduino board, and USB Human Interface Device (HID) communication to interact with the RFID reader. Upon detecting a valid RFID card, the system actuates a servo motor to a specified position and can further be extended to incorporate visual indicators and customizable behavior. This hands-on approach allows students to explore device interfacing, serial data processing, and hardware control using both Python and Arduino programming environments.

MATERIALS AND EQUIPMENT

ITEM	AMOUNT
LED	TBD
ARDUINO UNO MEGA	1
BREADBOARD	1
220 OHM RESISTANCE	7
JUMPER WIRES	9
RFID CARD READER	1
RFID TAGS OR CARDS	1
SERVO MOTOR	1
USB CABLE	1
MOUNT FOR SERVO	TBD

EXPERIMENTAL SETUP

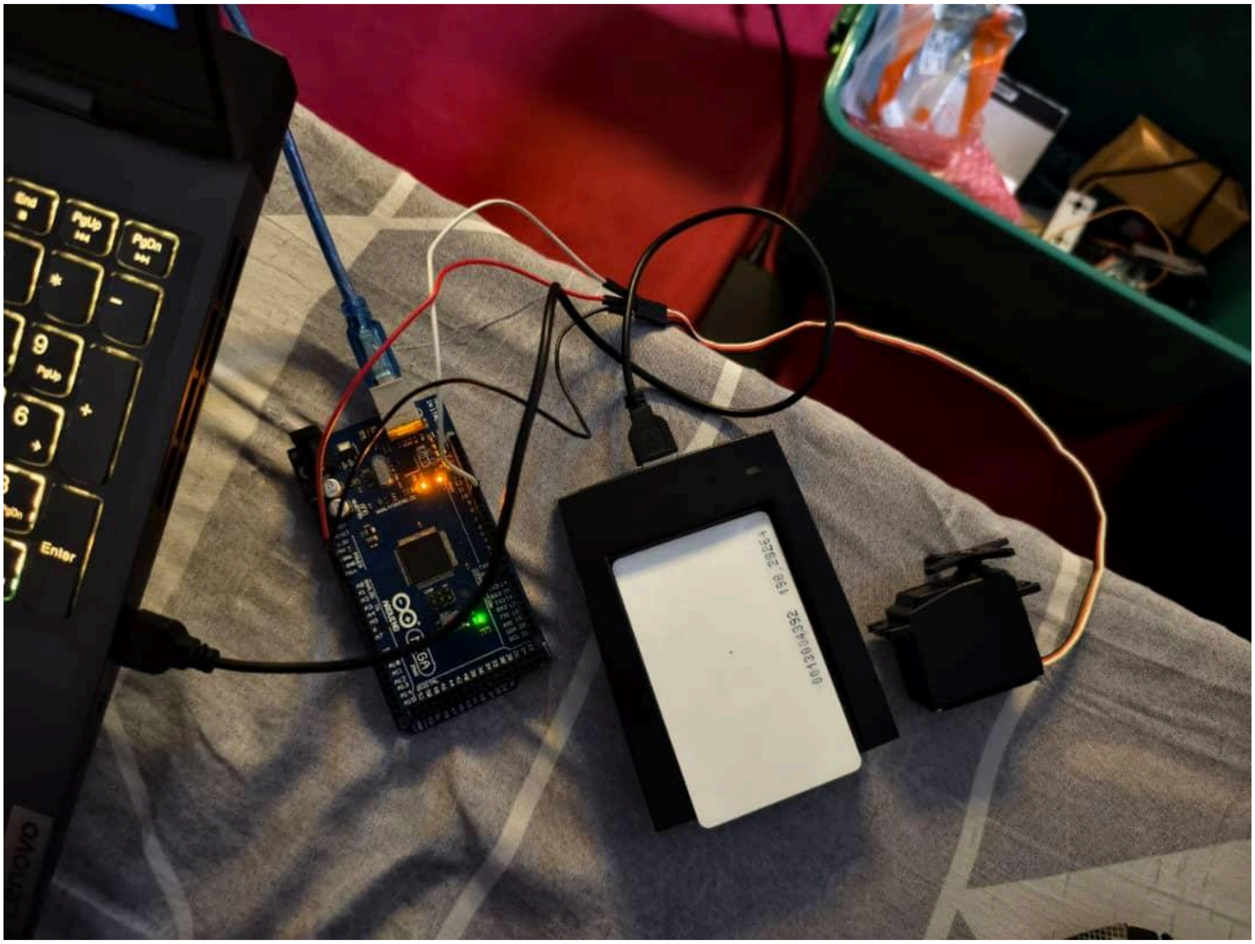
Hardware Connections

- RFID Reader: Connected to the computer via USB. No additional power wiring is needed as it draws power through USB.
- Servo Motor:
  - Power (Red) → Connected to Arduino 5V
  - Ground (Brown/Black) → Connected to Arduino GND
  - Signal (Yellow/Orange) → Connected to Arduino Digital Pin 9
- Arduino Board: Connected to the computer using a USB cable for power and serial communication.
- Common Ground: Ensured between the Arduino and servo motor to complete the circuit.

Software and Programming

- Arduino Code: Configured to control the servo motor based on serial input received from the computer. When an authorized RFID card is detected, a specific character ('A') is sent via serial to rotate the servo; otherwise, a different command ('D') resets it to a neutral position.
- Python Script:
  - Utilizes the pyusb library to interface with the USB RFID reader.
  - Detects and reads RFID tag data.
  - Compares tag data with a list of authorized IDs.
  - Sends corresponding commands to the Arduino over serial to control the servo motor.
  - Can be extended with LED indicators and JSON-based configuration handling.

RESULT



VIDEO LINK: TBA

DISCUSSION

The RFID-based authentication system developed in this lab illustrates the effective integration of sensor input (RFID reader) and actuator control (servo motor) via serial and USB communication using Python and Arduino. The project successfully demonstrates a simple access control mechanism where the detection of an authorized RFID card allows a servo motor to actuate, simulating physical access control such as opening a door or activating a device.

One of the key learning outcomes was understanding how USB Human Interface Devices (HID), like RFID readers, communicate differently from standard serial devices. This required the use of the pyusb library in Python to detect and read card data directly from the HID stream, showcasing an important concept in modern embedded systems: device-specific interfacing.

On the Arduino side, the servo motor responded accurately to commands received over the serial connection. This highlights the robustness and reliability of serial communication for real-time control tasks. By mapping specific characters ('A' for allow, 'D' for deny) to motor positions, the system was kept simple yet functional, which is ideal for prototyping and educational settings.

Challenges encountered included:

- Identifying the correct vendor and product IDs for the RFID reader, which are essential for USB communication.
- Managing the serial communication timing, especially ensuring the Arduino was ready to interpret incoming characters without delay or misreading.
- Ensuring a stable power supply for the servo motor, which can draw more current than the Arduino can safely provide under load.
- To enhance the system's feedback capabilities, LEDs can be added to visually indicate authentication results—green for access granted and red for denied. Moreover, by introducing structured data handling (e.g., JSON), the system could be made more flexible and scalable, allowing dynamic updates to authorized card lists and servo angle control via user-defined parameters.

Overall, the experiment effectively combines software and hardware components to achieve a practical application. It not only reinforces the concepts of serial and USB communication but also encourages thinking about real-world deployment considerations, such as reliability, safety, and user interaction.

CONCLUSION

This experiment successfully demonstrated the integration of an RFID card reader with an Arduino and Python to create an access control system with servo motor actuation. By leveraging USB HID communication and serial data exchange, the system effectively authenticated RFID cards and triggered servo movements based on predefined authorization rules. The inclusion of visual feedback through LEDs further enhanced user interaction, providing immediate status indications for granted or denied access. This setup highlights the practicality of combining RFID technology with microcontroller-based control systems for secure and automated applications.

The use of structured JSON data handling, as suggested in the task, would improve the system's flexibility, enabling easier management of authorized card IDs and servo angle configurations. Such an approach allows for dynamic adjustments without requiring code modifications, making the system more adaptable to different use cases. Additionally, incorporating user-defined servo angles adds a layer of customization, broadening the system's applicability in scenarios like door locks, robotic arms, or other position-based mechanisms.

Through meticulous hardware configuration and software validation, issues like preventing signal noise in the servo motor wiring or guaranteeing dependable USB connectivity with the RFID reader were resolved. Future enhancements might include wireless communication for remote monitoring or database integration for card management. These improvements would considerably simplify the scalability and functionality of the system.

To conclude, this experiment highlights how software logic and hardware elements work together in mechatronics systems. In addition to showcasing the flexibility of Arduino and Python in designing interactive, sensor-driven systems, it provides a fundamental illustration of how RFID technology can be used for secure access management. The concepts discussed here, which highlight the value of modular design and user-centric features, can be applied to more intricate automation projects.

RECOMMENDATIONS

In order to further increase the effectiveness, reliability, and usability of the RFID-based authentication and servo control system developed in this experiment, several significant recommendations are proposed. These recommendations aim to further improve both the technical robustness and user experience of the system and encourage further learning and development in mechatronic integration.

Firstly, it is highly recommended to improve the scalability and security of the authentication process. Instead of hardcoding authentic card IDs into the Python code itself, a more dynamic and scalable solution would be storing and keeping user information in an external JSON file or even a simple database like SQLite. This would allow easier updates and better data handling as the system is expanded to serve more users or different access levels.

Secondly, strengthening the visual feedback mechanism can make the system more usable. While green and red LEDs to signal granted and denied access are good, adding an LCD or OLED screen to display status messages (e.g., "Access Granted", "Access Denied", or

"System Ready") would provide more salient communication to end-users. Additionally, utilizing audible feedback in the form of a buzzer can offer yet another intuitive feedback mechanism.

Another important recommendation is the addition of error-handling routines and logging functions within the Python code. Such additions would help diagnose issues such as failure of USB connection, recognition of unknown devices, or incorrect reading. Incorporation of proper exception handling would render the system stable and responsive even in unexpected conditions.

Additionally, to enable further use cases and increase flexibility, it is advisable to include an option for a user input mechanism to dynamically configure the servo motor angle. Providing a graphical user interface (GUI) or command-line input for entering and showing the servo angle would allow users to customize the motor's behavior in real-time, providing an even broader range of potential uses.

Lastly, for improved hardware safety and performance, it is suggested that an external power source for the servo motor be employed if more torque or extended operating times are required. The Arduino's onboard power may not be sufficient for high-usage applications of the servo, which will result in unstable behavior or damage.

Overall, the implementation of these recommendations would not only enhance the current experimental setup but also serve as a foundation for developing a more complete and real-world applicable mechatronic system. These upgrades enable ongoing learning, encourage innovation, and promote best practices in system design and integration.

ACKNOWLEDGEMENT

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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 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 no further improvement on the reports is needed from any of the individual's 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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