



ITAHARI INTERNATIONAL COLLEGE

Cloud Computing and Internet of Things (Proposal)

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I confirm that I understand my coursework needs to be submitted online via MySecondTeacher under the relevant module page before deadline for my assignment to be accepted and marked. I am fully aware that late submission will be treated as non-submission and mark of zero will be awarded.

Acknowledgement

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Crack – 0

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Abstract

This project investigates the development of a gesture-controlled robotic arm using Internet of Things (IoT) and wearable sensor technology. The system integrates flex sensors, MPU6050 motion units, Arduino microcontrollers, Bluetooth communication, and servo-based actuation to enable real-time replication of natural hand and wrist movements. By interpreting finger bending and hand orientation through a wearable glove, the robotic arm performs coordinated tasks such as joint rotation, arm lifting, and object gripping with smooth and responsive motion.

By addressing challenges such as the high cost, limited accessibility, and complexity of existing assistive robotic systems, this project offers a practical and affordable alternative suitable for both personal and industrial use. The system architecture is designed to be modular and extendable, allowing additional sensors, improved control modes, or enhanced mechanical features to be incorporated in the future.

The outcomes of this project demonstrate the practical application of IoT and embedded systems in improving independence for individuals with upper-limb impairments, reducing physical strain in repetitive industrial tasks, and enhancing human–machine interaction. This work serves as a learning platform for applying modern sensing technologies in real-world problem-solving while contributing to the growing field of intelligent assistive robotics.

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1 Introduction

In the world of advancements, IOT (Internet of Things) technologies, embedded systems, micro-controllers, and wearable technology sensors play a significant role in transforming the domain of human-machine interaction. Among all, the gestured robotic arm is one of the most impactful and highly researched IOT developments that help to perform manipulation to mechanical parts like joints and grippers using the natural wrist and hand movements. IOT innovations have gained an increasing importance in the current world landscape due to its ability to replicate human arm movements in real-time using natural gestures. It is a powerful and emerging technology advancement alternative to the traditional robotic architectures with its low-cost microcontroller components like Arduino Nano/ Uno, flex sensors, accelerometers, and measurable units (IMUs) that imitate the human motions and drive the robotic motors and actuators with a responsive and precise robotic motion.

1.1 Current scenario

The worldwide demand for gesture-controlled robotic arms is increasing rapidly. About **1.3 billion** peoples (**16%** of the total world population) lives with significant disabilities, and more than **30 million** individuals have upper-limb impairments requiring excessive support for their day-to-day work. (Juraev, September-30,2025) Traditional prosthetic systems can cost up to an estimated budget of around **USD \$5,000 - \$50,000**, placing this equipment far beyond the reach of most individuals and various institutions demanding gesture-controlled technologies. In contrast, motion-controlled robotic prototypes can reduce the cost to **about 95-99%** compared to the commercial technologies and can help to make a major impact on wider global audiences in need of these technologies. (Hideyuki Tanaka, 2013)

Moreover, the IJSRD study on hand gesture-controlled robotic systems demonstrated that the Arduino-based robotic arms manipulated via IOT devices achieved accurate and smooth motion capabilities, showing a strong potential in automation and remotely controlled robotic systems. Similarly, a study in industrial automotive assembly lines found that workers perform an average of **4,600** overhead manipulations each day, which is a primary cause for musculoskeletal disorders (MSDs) that hold a proportion of **over 15%** workdays in manufacturing (Cherubini, October 11, 2023)

1.2 Problem Statement and Project as a Solution

Individuals with upper-limb impairments often struggle to perform daily tasks independently because most existing assistive systems lack natural, intuitive control methods (Liang & D.A, 2014). At the same time, industrial workers face repetitive and physically demanding motions—such as thousands of overhead movements per day—that lead to fatigue, musculoskeletal disorders, and reduced productivity (Davidson, 2010). Both situations highlight a need for a responsive, gesture-based robotic system that can accurately mirror human arm movements in real time (Yavuzer, 2009).

To address this, the project proposes a hand-gesture-controlled robotic arm that uses wearable sensors to capture natural wrist and finger movements and translate them into smooth robotic acting. By enabling human-like motion replication through simple gestures, the system supports users with limited mobility while also reducing physical strain in industrial environments. This approach provides a practical, user-friendly assistive tool that improves independence, safety, and efficiency across multiple real-world applications.

2 Aim and Objectives

2.1 Aim

To make a Bluetooth-controlled robotic arm prototype.

2.2 Objectives

- To design and construct a Bluetooth-controlled robotic arm using servo motors and Arduino.
- To implement gesture-based control using a flex sensor and accelerometer.
- To achieve repeatable and smooth servo movement through proper control algorithms.
- To evaluate the propositional repeatability of the robotic arm through practical testing.
- To demonstrate the object pick and place operation.

3 Background

3.1 Expected Outcomes and Deliverables

The gesture-controlled robotic arm is a device that can be used to simulate the movements of a human hand in real-time. It is a wearable glove that contains sensors that identify the bending of fingers and hand positioning. These sensors feed information to a microcontroller, which processes the information and sends it wirelessly to the robotic arm. The arm has a number of servo motors, and it is its microcontroller that deciphers these signals to move its joints and gripper according to the movements of the user. This is a configuration that enables users to control the robotic arm intuitively and by hand, and this means that complex motion can be imitated by the arm, and the arm can replicate the motion correctly.

User Input via Glove

- The user wears the gesture control glove.
- The glove has sensors to capture:
 - **Flex sensors:** detect bending and finger motions.
 - **IMU/Accelerometer:** detects hand orientation and tilt.

Data Processing in a Glove

- All sensor readings are collected by the microcontroller on the glove (e.g., Arduino).
- The microcontroller converts the analog signals from the sensors into digital commands.

Wireless Transmission

- The glove sends the processed sensor data wirelessly using a Bluetooth or Wi-Fi module.
- This ensures the user can control the robotic arm remotely without cables.

Receiving Data in Robotic Arm

- The robotic arm unit has a wireless receiver (Bluetooth/Wi-Fi) that gets the commands.
- Its microcontroller (Arduino/ESP32) interprets the incoming data.

Servo Motor Control

- Based on the commands, the microcontroller controls the servo motors of the robotic arm:
 - **Base rotation:** turns the arm left/right.
 - **Shoulder joint:** moves the upper arm up/down.
 - **The elbow joint:** bends or straightens the arm.
 - **Wrist tilt/rotation:** rotates or tilts the wrist.
 - **Gripper:** opens and closes the hand.

Power Supply

- Servos and microcontrollers are powered by a 5V/12V supply, depending on servo requirements.

Arm Replicates Hand Movements

- The robotic arm mimics the exact movements of the user's hand and fingers in real-time.

The figure below shows this process visually.

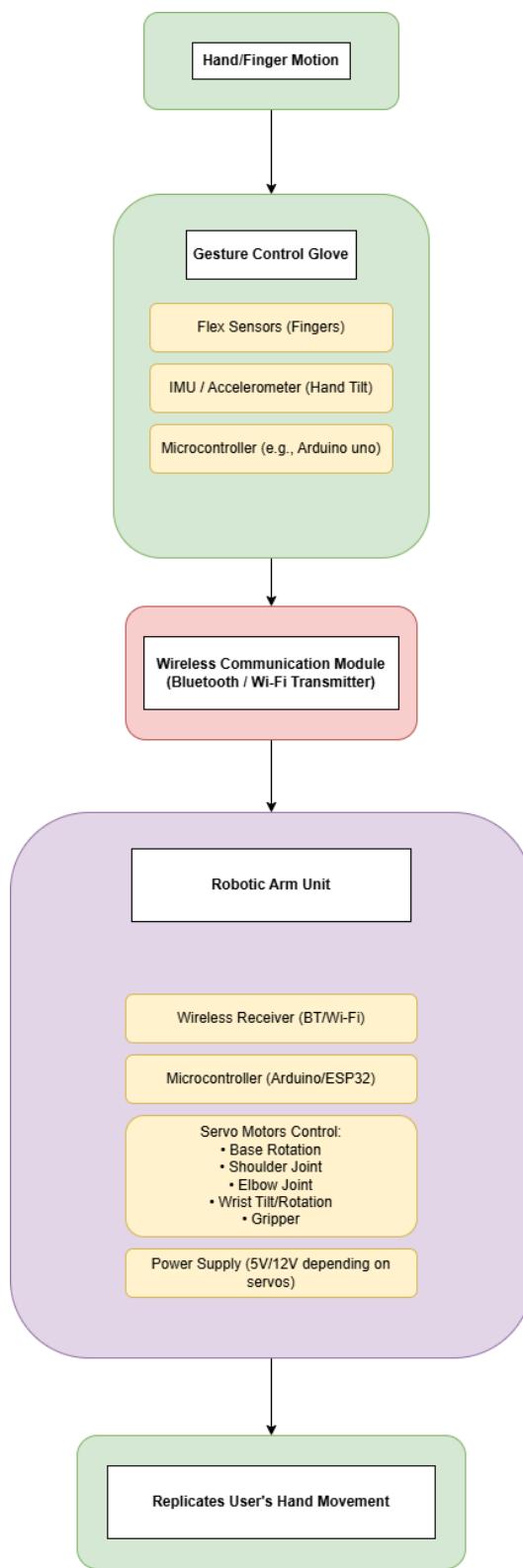


Figure 1: System Architecture

3.2 Requirement Analysis

3.2.1 Gesture-Controlled Glove (Input Subsystem)

Flex Sensors (3 Units)

Justification:

Flex sensors are essential for detecting finger movements. They serve as the primary source of gesture input, allowing the system to interpret how much each finger bends.

Function :

A flex sensor changes its electrical resistance based on the degree of bending. When the finger moves, the sensor flexes, causing a measurable change in resistance. This resistance change is converted into voltage using a voltage divider circuit. The Arduino Nano reads this analog voltage, which corresponds to the bending level. This enables accurate tracking of finger motion in real time.

Role in Process:

- Mounted on glove fingers.
- Finger bending causes resistance changes, which in turn change the analog voltage.
- Arduino Nano converts voltage into numeric finger-position values.
- Values are packaged and transmitted to the robotic arm for replication.

MPU6050 Accelerometer + Gyroscope (2 Units)

Justification:

Required to track the overall orientation and movement of the hand, including tilting, rotation, and motion dynamics.

Function :

The MPU6050 integrates a 3-axis accelerometer and a 3-axis gyroscope. The accelerometer senses linear acceleration and static tilt, while the gyroscope measures angular changes such as rotation or twisting. Through the I2C communication interface, the Arduino Nano continuously reads 6-axis motion data. This allows the system to detect wrist orientation and dynamic hand gestures like lifting, twisting, or turning.

Role in Process:

- Mounted on the backside of the glove
- Tracks wrist orientation and movement
- Provides data for controlling robotic arm angles or base rotation

Arduino Nano**Justification:**

Serves as the central controller for the gesture glove, responsible for managing sensors, processing inputs, and transmitting gesture data.

Function :

The Arduino Nano reads analog values from the flex sensors and digital motion data from the MPU6050 through the I2C protocol. It processes this sensor data by filtering noise, normalizing values, applying calibration equations, and converting the readings into meaningful gesture commands. It then formats the data into serial packets suitable for Bluetooth transmission.

Role in Process:

- Reads and interprets glove sensor data
- Converts gestures into structured control commands
- Sends commands wirelessly to the robotic arm subsystem

HC-05 Bluetooth Module (Transmitting Module)**Justification:**

Enables wireless communication between the glove and the robotic arm, allowing complete mobility and a real-time control experience.

Function :

The HC-05 Bluetooth module handles serial communication between the Arduino Nano and the receiving module. It converts digital data into Bluetooth packets and transmits them

wirelessly using classic Bluetooth protocols. It ensures low-latency and stable data transfer suitable for real-time robotic control.

Role in Process:

- Transmits gesture commands from the glove
- Ensures wireless control between the user and the robotic arm

3.7V Lithium-Ion Battery**Justification:**

Provides portable power to the glove without requiring any wired connection, enabling full wearable functionality.

Function :

The Li-ion battery supplies consistent voltage to the Arduino Nano, sensors, and Bluetooth module. It maintains sufficient current output to ensure uninterrupted operation. When used with a voltage regulator, it ensures stable power distribution across all components.

Role in Process:

- Powers glove electronics
- Allows wireless and portable gesture tracking

Resistors (10KΩ, 1KΩ, 220Ω)**Justification:**

Required for building proper sensor circuits, protecting components, and ensuring accurate signal readings.

Function :

- **10KΩ Resistors:** Form voltage divider circuits with flex sensors, converting resistance variations into measurable voltages.
- **1KΩ Resistors:** Used for signal stability and noise reduction in analog lines.

- **220Ω Resistors:** Primarily used for limiting current to indicator LEDs or protecting digital output pins.

Role in Process:

- Maintain safe voltage levels
- Improve reliability of sensor data
- Prevent electrical damage

100nF Capacitors**Justification:**

Used to reduce electrical noise and stabilize power for sensors and microcontrollers.

Function :

These capacitors are connected across power lines to filter out voltage fluctuations caused by sudden current changes. They help smooth the power supply, improve the stability of analog readings, and prevent erratic behavior in sensitive modules such as the MPU6050 and HC-05.

Role in Process:

- Ensures cleaner analog signals
- Provides stable power to sensors and microcontroller

Jumper Wires**Justification:**

Required to establish electrical connections between all glove components.

Function :

Carry power, ground, analog signals, and serial communication lines between sensors, the Arduino Nano, and the Bluetooth module.

Role in Process:

- Connect components into a complete wearable system

3.2.2 Mechanical Robotic Arm (Output Subsystem)

MG996R High-Torque Servos (3 Units)

Justification:

Provide the main actuation force required to move the robotic arm's major joints such as shoulder, elbow, and base rotation.

Function :

MG996R servos accept PWM signals from the Arduino Uno and convert them into precise angular rotations. Their high torque allows them to lift and move mechanical structures efficiently. They include internal position feedback to accurately maintain the commanded angle.

Role in Process:

- Execute large joint movements
- Replicate user gestures received from the glove

SG90 Micro Servos (3 Units – Optional)

Justification:

Used for sub-joints or lightweight motions such as robotic fingers or wrist articulation.

Function :

SG90 servos provide lower torque but more precise angular movements. They respond quickly to PWM signals from the microcontroller and are ideal for delicate movements like gripping or opening/closing fingers.

Role in Process:

- Control fine motions

- Allow detailed replication of finger gestures

MPU6050 (Optional Feedback Sensor)

Justification:

Used for implementing feedback control, which improves stability and precision in advanced robotic arm systems.

Function :

Measures the arm's orientation and movement. When used in a feedback loop, the Arduino can compare actual arm position with the desired position and correct errors in real time.

Role in Process:

- Enhances accuracy
- Improves stability and smoothness (if implemented)

Arduino Uno

Justification:

Serves as the primary controller for the robotic arm, receiving gesture commands and generating servo control signals.

Function :

The Arduino Uno receives Bluetooth data from the glove. It interprets gesture values and converts them into servo angles. It drives the servos through PWM outputs, ensuring appropriate speed and rotational limits. It also manages power distribution and optional feedback sensors.

Role in Process:

- Receives gesture commands
- Translates commands into servo movements
- Coordinates all actuators on the robotic arm

HC-05 Bluetooth Module (Receiver)

Justification:

Required to receive wireless gesture data from the glove.

Function :

This module pairs with the transmitting HC-05 on the glove. It receives incoming Bluetooth packets, decodes them, and sends serial data to the Arduino Uno for processing.

Role in Process:

- Provides wireless communication to the robotic arm
- Enables real-time gesture replication

USB 5V Power Adapter / Transformer

Justification:

High-torque servos require more current than the Arduino can supply; therefore, an external power source is necessary.

Function :

Provides stable 5V DC with sufficient current capacity (typically 2A–5A) to power multiple MG996R servos. Prevents voltage drops that could cause microcontroller resets or servo malfunction.

Role in Process:

- Powers high-torque servos
- Ensures smooth and stable arm operation

Jumper Wires**Justification:**

Required for connecting servos, Bluetooth module, power adapter, and Arduino Uno.

Function :

Carry PWM signals, power, and communication lines necessary for the entire robotic arm subsystem.

Role in Process:

- Enable full electrical connectivity and operation

5 Individual Contribution Plan

5.1 Work Breakdown Structure(WBS)

Work Breakdown Structure, a common technique of breaking down work into smaller tasks. It makes the work more manageable and approachable. According to PMBOK (Project Management Book of Knowledge), WBS is defined as "deliverable-oriented hierarchical decomposition of the work to be executed by the project team".

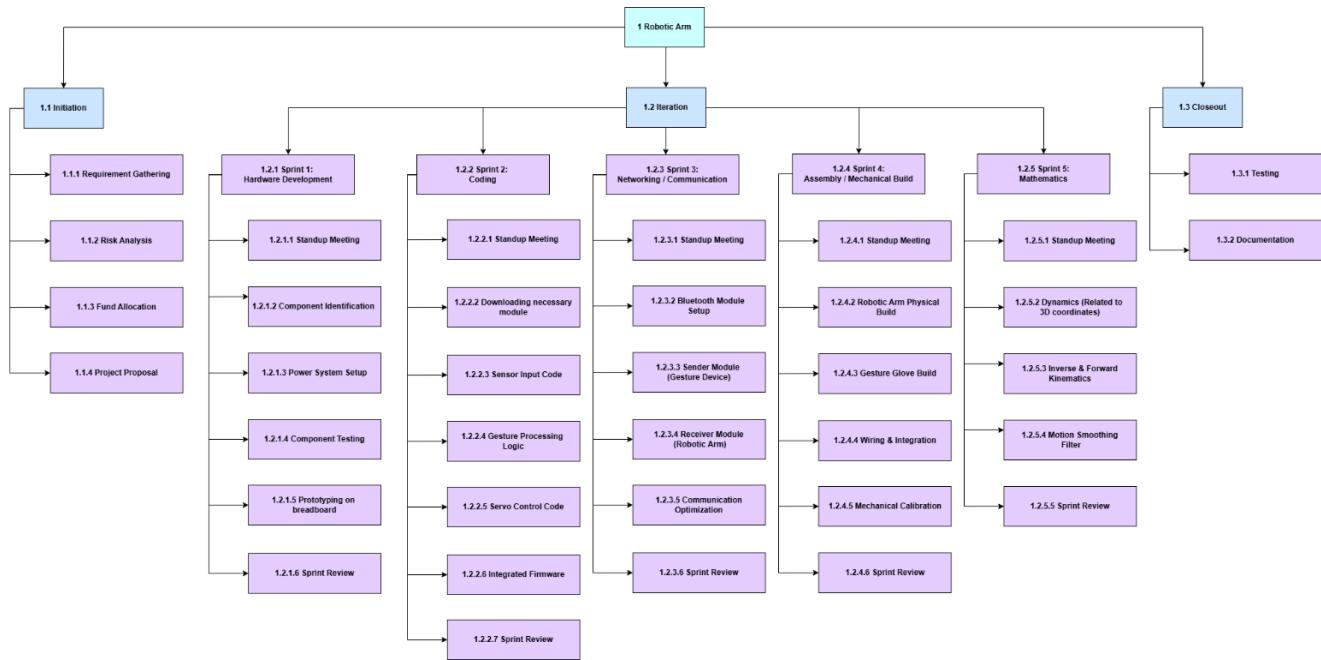


Figure 2: Work Breakdown Structure

The following section presents a detailed breakdown of the project tasks along with the assigned stakeholders responsible for each task.

Table 1: Task Distribution Table

| S. N | Task | Members Assigned | Description |
|------|-----------------------------|------------------------------------|--|
| 1 | Hardware Development | Sushant Kulung and Prajwal Koirala | All required hardware components for the robotic arm are identified, collected, and tested for proper functionality. This includes checking sensors, servos, microcontrollers, wiring, and power units before integration. |
| 2 | Coding | Samir Nepal and Sujal Shrestha | The necessary software modules are set up, including Arduino IDE configuration and library installation. Code is developed for reading gesture inputs, processing sensor data, and controlling the robotic arm's servo movements. |
| 3 | Networking / Communication | Sujal Shrestha and Subin Shrestha | Wireless communication between the hand-gesture glove and the robotic arm is established and tested. This task includes Bluetooth configuration, pairing, data transfer setup, and integrating communication logic into the main control system. |
| 4 | Assembly / Mechanical Build | Sushant Kulung and Subin Shrestha | All mechanical and electronic components of the robotic arm are assembled, including servo mounting, frame construction and wiring organization |
| 5 | Mathematics | Samir Nepal and Prajwal Koirala | Mathematical models are developed for angle mapping, motion smoothing, and positioning the robotic arm in 3D space. This includes calculations for servo rotation, gesture-to-movement translation, and gripper control. |
| 6 | Testing / Documentation | All Team Members | The complete system is tested for accuracy, stability, and reliability. All procedures, designs, diagrams, calculations, and results are documented for reporting, presentation, and future reference. |

6 Conclusion

The rapid growth of IoT technologies, embedded systems, and wearable sensors has opened new possibilities for creating assistive and collaborative robotic solutions. The analysis presented in this proposal clearly shows that gesture-controlled robotic arms have the potential to address two significant global challenges, such as the lack of accessible support for individuals with upper limb impairments and the physical strain experienced by industrial workers performing repetitive tasks. With more than 1.3 billion people living with disabilities and thousands of daily overhead movements contributing to musculoskeletal disorders in manufacturing environments, there is a clear need for a system that combines precision, affordability, and natural human-machine interaction.

This project aims to meet that need by designing a low-cost gesture-controlled robotic arm capable of interpreting real-time hand and wrist movements through flex sensors, accelerometers, and microcontroller platforms such as Arduino. By offering intuitive control, the system seeks to provide improved independence for users with mobility limitations and reduce physical workload in industrial settings. More importantly, it demonstrates how modern sensor technologies and IoT integration can deliver practical, scalable solutions that benefit both individual users and larger work environments.

Overall, the proposed system represents more than a technical prototype: it is a step toward making assistive robotics more accessible, more responsive, and more aligned with natural human movement. Its development highlights the potential for technology to enhance quality of life, promote safer working conditions, and contribute to the ongoing advancement of intelligent, human-centred robotic systems.

7 References

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8 Appendix

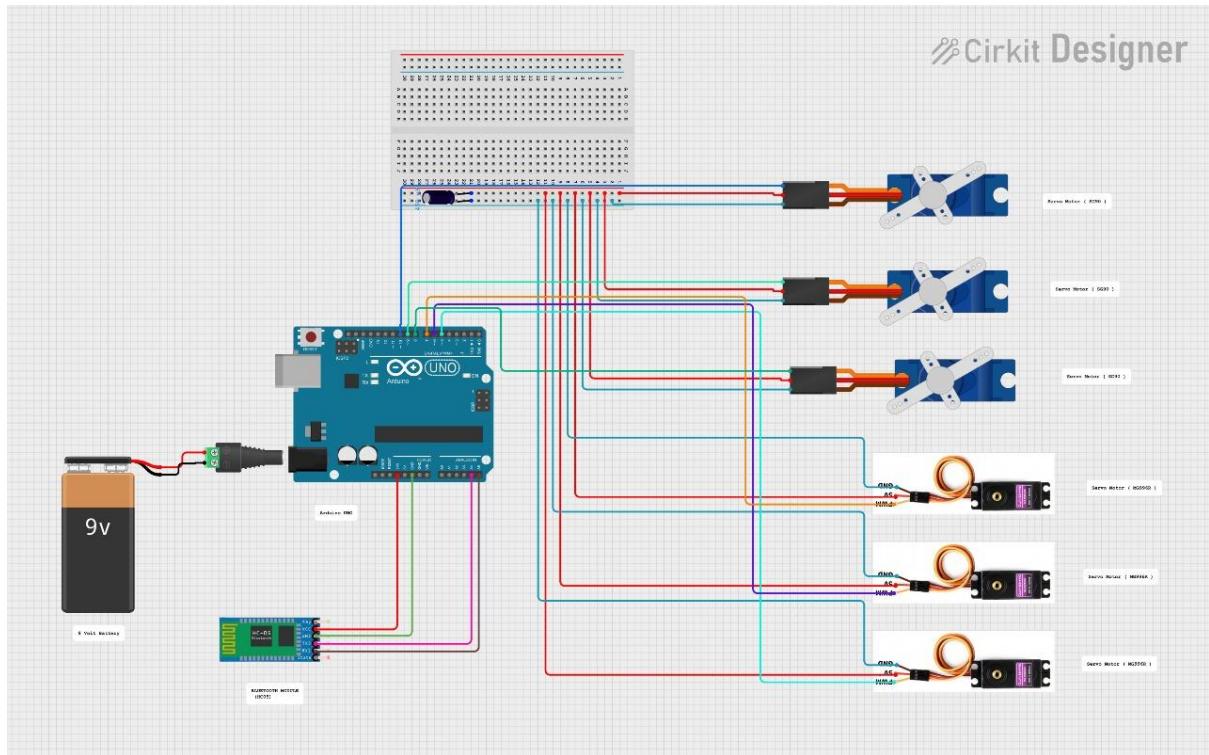


Figure 3: Robotic Arm Circuit Diagram

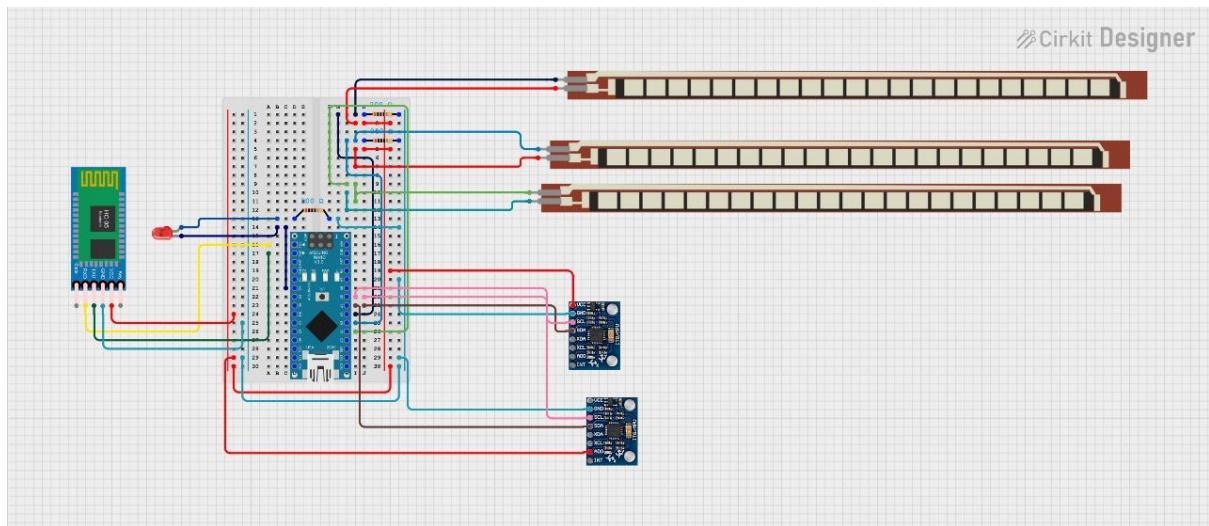


Figure 4: Robotic Gloves Circuit Diagram