CHAPTER 1
INTRODUCTION

1.1 INTRODUCTION OF ROBOT ARM

The field of human-robot interaction (HRI) has expanded significantly with the development of more natural and accessible control interfaces. Traditional control solutions for robotic arms, such as joysticks, keyboards, or touchscreens, frequently necessitate technical knowledge and can hinder the intuitive operation required for complicated or dynamic jobs. To solve these restrictions, gesture-based control systems have developed as a novel approach, allowing people to control robotic arms using basic hand movements. This development has the potential to improve the efficiency and usability of robotic systems across a wide range of applications.

Gesture-controlled robotic arms use sensors and recognition algorithms to interpret hand gestures and translate them into real-time commands for the robot. By capturing the user's hand movements, the system enables precise control of the robotic arm's movements, offering a more user-friendly alternative to traditional methods. Gesture-based control systems hold promise in various sectors, including industrial automation, medical assistance, rehabilitation, and remote operations, where hands-free control can enhance accessibility, safety, and efficiency.

This method has the potential to simplify robot operation, increase precision, and minimize cognitive strain on humans, making it extremely useful in industries such as manufacturing, healthcare, assistive technology, and remote operations.

1.2 ROBOTICS

A robot is a computer-programmable machine that can automatically perform difficult tasks. Robotics is an interdisciplinary field of engineering and computer science. It includes the design, manufacture, operation, and use of the robots. These laws should be valid for the Robots:

1) A robot must not inflict harm on a human or allow harm to come to a human through inaction.

2) A robot is required to obey human orders unless such actions conflict with the First Law.

3) A robot must protect its own existence unless it conflicts with the First or Second Law.

1.2.1 TYPES OF ROBOTICS

There are various kinds of robots that can be employed for various purposes. These robots reduced time and human complexity by being designed based on needs.

1. **Pre-Programmed Robots**

   These are robots that can be programmed using Arduino, Raspberry Pi, and others. These robots can be employed in the automobile industry for tasks like pick and place and IC manufacture. To increase precision, these can have a feedback loop.

2. Autonomous Robots

These robots must function on their own without assistance from humans. Because they employ sensors to assist them comprehend their surroundings and make decisions that may be the best ones depending on the circumstances. They require much more computation and data transmission

Roomba Vacuum cleaner.

1.2.2 APPLICATION

Robotic arms have a wide range of applications across various industries due to their precision, strength, and versatility. Here are some key applications:

1) **Manufacturing and Assembly**: Used for welding, assembling parts, painting, and packaging in automotive and electronics industries.
2) **Healthcare**: Assist in surgeries with high precision (e.g., robotic-assisted surgeries) and in-patient rehabilitation, such as robotic exoskeletons.
3) **Military and Defence**: Used in bomb disposal, surveillance, and search-and-rescue missions in hazardous zones.
4) **Food and Beverage**: Assist in food preparation, packaging, and quality control to maintain hygiene and speed.
5) **Logistics and Warehousing**: Used for picking, sorting, and palletizing goods to streamline warehouse operations and supply chains.
6) **Space Exploration**: Operate in harsh environments, like Mars rovers, to conduct research and collect samples remotely.

1.2.3 SCOPE OF ROBOTICS

Robotics can be considered as the Field of combination of Robotic technology and the Artificial Intelligence. These Robotic Engineer can work with different organization like the ISRO, NASA etc. Even the developed countries were now trying to use Robots for various industry to increase their productivity. So this also account for increasing the Scope of Robotics in the Future. There are courses for the Robotic engineering in the institutes like IIT, NIT, BITS, VIT etc.

Advances in machine learning, artificial intelligence, sensor technologies, and downsizing will play a major role in the future reach of robotic arms. These developments will make robotic arms more intelligent, versatile, and able to carry out a wider variety of jobs in many industries.

1.3 HUMAN MACHINE INTERACTION

Human-machine interaction is a key component of a successful robotic system. Programming was the sole method of communication with a robot in the early days, and it took a lot of effort. Gesture-based recognition became a reality as science and robotics advanced.

Gestures can come from any movement or condition of the body, although they usually start with the hand or face. One method for computers to comprehend human body language is through gesture recognition. As a result, fewer text interfaces and GUIs (Graphical User Interface) are now required.

1.4 PROBLEM STATEMENT

In today's fast-paced world, there is a growing need for assistive technology that can help individuals with physical disabilities, the elderly, and people working in hazardous environments carry out daily tasks independently.

This project aims to develop a robotic arm controlled by human gestures, focusing on meeting basic human needs, such as assisting with feeding, object handling, and personal care.

1.5 OBJECTIVES

Our objective is to make this device simple as well as cheap so that it could be mass produced and can be used for several purposes.

Implementing a robotic arm are centered on improving productivity, precision, safety, and automation across various industries.
Here are key objectives:

- ❖ Increased Efficiency and Productivity.
- ❖ Enhance Precision and Accuracy.
- ❖ Reduce Human Labor and Fatigue.
- ❖ Improve Safety in Hazardous Environments.
- ❖ Adaptability for Multiple Tasks.

1.6 OVERVIEW

A mechanical apparatus that replicates the motion and functionality of a human arm is called a robotic arm. Robotic arms are utilized for a broad range of jobs and are highly programmable due to their strength, accuracy, and adaptability. Multiple degrees of freedom are made possible by their linked segments, or "links," which are powered by joints that may include linear or rotational actuators.

Key Components of a Robotic Arm:

- Joints and Links.
- End Effector.
- Sensors.
- Control System.
- Actuators.

Types of Robotic Arms:

1) **Articulated Robots:** These have rotary joints and resemble a human arm, offering multiple degrees of freedom.
2) **Cartesian Robots:** Operate on three linear axes (X, Y, Z) and are used in tasks requiring straight-line movement, such as CNC machining.
3) **SCARA Robots (Selective Compliance Articulated Robot Arm)**: These have horizontal movement capabilities, making them ideal for tasks like assembly and packaging.

CHAPTER 2
LITERATURE REVIEW

Literature reviews are the foundation for research in almost every academic subject. A narrow-scope literature review may be presented as part of a peer-reviewed journal article reporting new research, helping to contextualize the current study within the body of relevant literature and providing context for the reader. They should not be confused with book reviews, which may also appear in the same magazine.

A scientific work that incorporates current knowledge, substantive results, as well as theoretical and methodological contributions to a specific issue. Such evaluations are most connected with academic literature and may be found in academic journals. In such cases, the review typically comes before the technique and outcomes parts of the study.

2.1 Design and Development of Gesture Controlled Robotic Arm

The field of gesture-controlled robotics has seen substantial growth, as recent developments in human-robot interaction have led to more natural, intuitive control methods. Gesture-controlled robotic arms are gaining momentum in a variety of industries, including medical, industrial, and assistive technologies, since they provide safe and accessible methods to interface with equipment. These systems rely largely on two approaches: vision-based and sensor-based gesture recognition. Vision-based approaches use cameras and machine vision algorithms to collect and analyze hand gestures, which are then converted into orders for the robotic arm. This method, which is frequently supplemented by software like as OpenCV, enables real-time gesture control and has a wide range of applications, including assistive devices and interactive displays.

Overall, gesture-controlled robotic arms hold significant potential for advancing human-robot interaction. The current literature suggests that with continuous improvements, gesture-controlled robotics will further integrate into sectors requiring precision, safety, and natural user interfaces. This expanding technology is set to reshape industries by making robotics more adaptable, enhancing productivity, and enabling new applications across healthcare, industrial automation, and interactive environments.

AUTHOR: Dr. Prathibha Kiran, Dr. Jagadeesha S, Sonu S, Priyanka N, Mohammed Shahid, Syed Suleiman Kaleem.

YEAR: August 2024

2.2 Gesture-Controlled Robotic Arm

Gesture-controlled robotic arms represent an advancement in robotics by enabling natural, intuitive interaction through hand movements. These systems, often designed with sensors like flex sensors, gyroscopes, and microcontrollers, translate hand gestures into real-time robotic actions. This approach finds applications in various fields such as industry, where robotic arms perform complex, repetitive tasks, and in healthcare, assisting individuals with disabilities. Compared to traditional control methods, gesture-based systems enhance accessibility and reduce the need for direct user contact. Recent developments focus on improving sensor accuracy, response time, and adaptability, paving the way for broader integration of gesture-controlled robotics in diverse environments.

AUTHOR: Md Musfiq Us Saleheen, Md Rabbul Fahad, Riasat Khan

YEAR: May 2023

2.3 Hand Gesture Recognition and Control for Human-Robot Interaction Using Deep Learning

The project report on a robot arm controlled by hand gestures typically involves an introduction to hand gesture recognition technology, its applications, and relevance in fields like industrial automation and hazardous environment control. It discusses the methodology, including the hardware components like cameras for gesture tracking, robotic arm controllers, and processing units. Software aspects involve training convolutional neural networks (CNNs) to classify gestures and translate them into commands for robotic arm movement. The report would also include testing phases to assess recognition accuracy, response times, and any environmental challenges, such as lighting variations. Finally, it outlines the results, improvement areas, and potential future developments for more robust, versatile control systems, enhancing human-robot interactions in complex settings.

AUTHOR: Philip Jonah Ezigbo, Onyebuchi Chikezie Nosiri, Ekene Samuel Mbonu, Victor Ofor, and Jude Obichere

YEAR: November 2023

2.4 Robot ARM with Gesture Control

The project report on a gesture-controlled robotic arm presents an innovative system enabling intuitive human-robot interaction in challenging environments like radiation zones or disaster areas. It integrates a low-cost, microcontroller-based design that leverages accelerometers and gesture recognition for controlling robotic movements. The system utilizes an accelerometer to capture hand gestures, transmitting data wirelessly via RF modules to a microprocessor, which processes the gestures and controls the robotic arm's servos accordingly. Arduino microcontrollers provide flexibility and ease in programming, and servo motors, essential for precise control, mimic human hand motions like grasping and rotating. With applications in prosthetics and industrial automation, this robotic arm system showcases practical advancements in robotic prosthetics and remote robotic control.

Additionally, with flexible components such as the flex sensor and breadboard, the arm can integrate with additional sensors or adaptive systems, expanding its applications further into areas like prosthetics and industrial automation. In prosthetics, for example, a gesture-controlled arm can assist amputees with daily tasks by replicating natural hand movements.

AUTHOR: N Nissi Kumar, P Sai Tharun, K. Prakash, L.M.N Mythresh, Naga Jyoshna

YEAR: June 2022

2.5 GESTURE CONTROLLED ROBOTIC ARM

The project aims to develop a robotic arm that can be controlled through hand gestures, enabling it to perform specific tasks such as picking and placing objects. Key components include an Arduino board as the main controller, servo motors acting as actuators, and sensors like the MPU6050 (gyroscope and accelerometer) and flex sensors. These sensors detect hand gestures, translating them into corresponding movements in the robotic arm. The arm's design has evolved through multiple versions, with improvements in accuracy and performance achieved by combining different sensors and employing the NRF24L01 module for wireless communication. This project highlights the application of robotics in automation and could have implications in industries requiring precision tasks, reducing human effort and error.

Different versions of the robotic arm have been developed, with each iteration enhancing accuracy, reducing response delays, and refining movement control. For example, using both MPU6050 and flex sensors together in Version 3 improved flexibility and allowed for more responsive control.

AUTHOR: *DR. Emjee Puthooran*

YEAR: June 2022

2.6 Gesture Controlled Robotics Hand

The project focused on developing a robotic hand operated by human gestures, with applications in fields like military, medical surgeries, and industrial automation. The system uses flex sensors and an Arduino Nano to replicate human hand movements in the robotic hand. This design is particularly useful for tasks in hazardous environments, like bomb defusal or firework handling, where human safety is a concern.

The project setup includes a glove with embedded flex sensors that transmit signals via a wireless transceiver, which then interprets the gestures and translates them into precise finger movements in the robotic hand. This innovative approach enables real-time control, allowing the robotic hand to mimic the wearer's hand motions.

The implementation involves both mechanical and electronic components, including servos for movement and transceivers for communication, highlighting the potential of gesture-based technology in enhancing human-machine interaction.

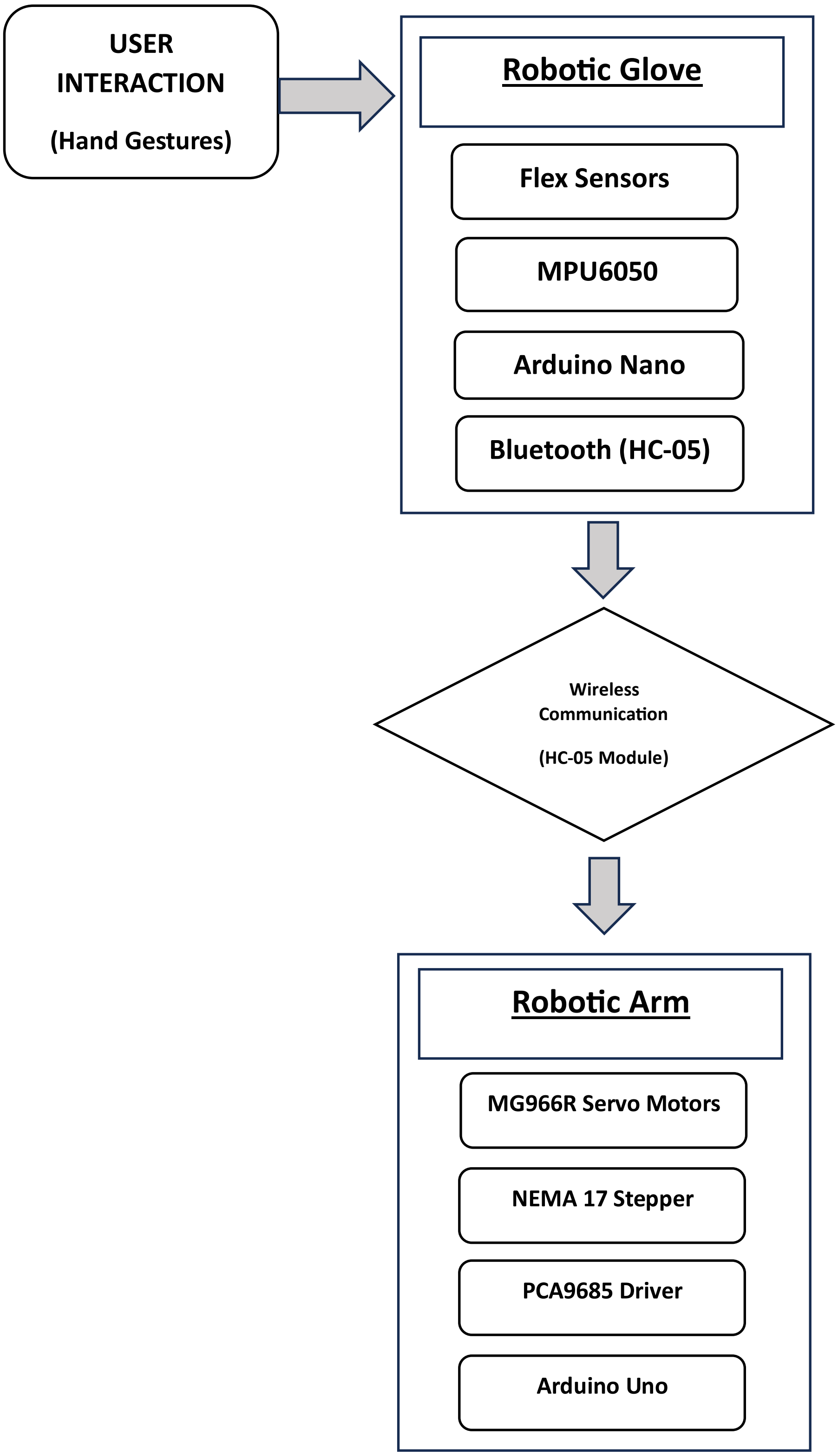
AUTHOR: Dr. Katherasan Duraisamy, Lenin. S. A, Rahul. S, Reshma. R, Sanjay. C

YEAR: May 2022

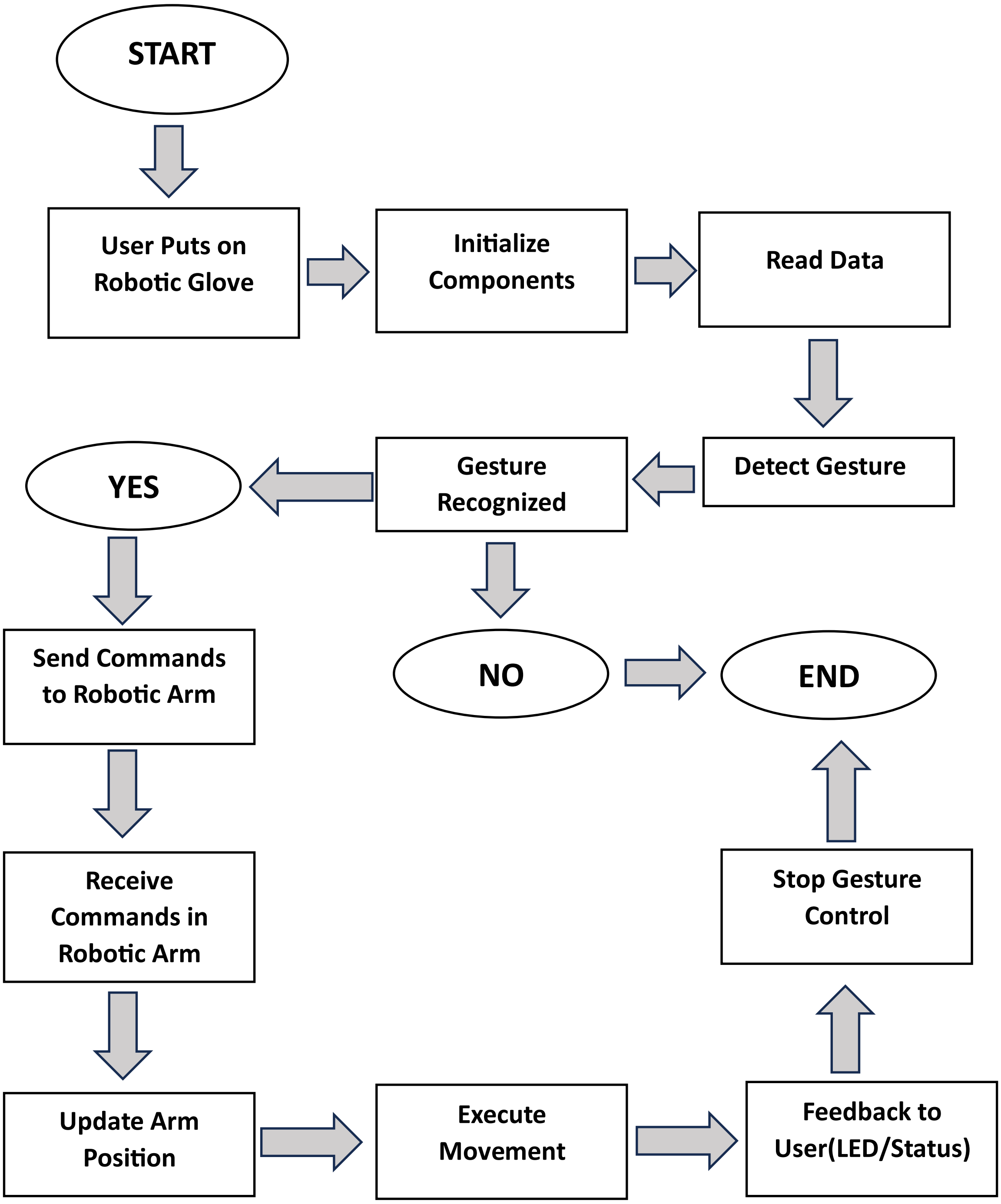
CHAPTER 3

SYSTEM DESIGN

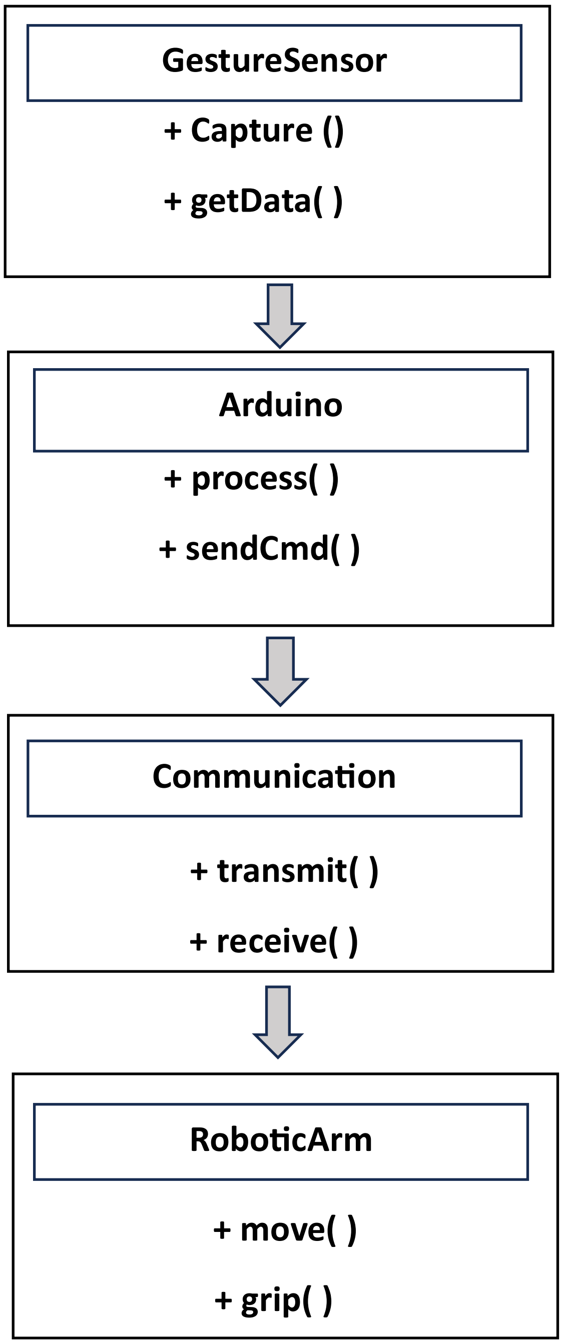
3.1 SYSTEM ARCHITECTURE



3.2 ACTIVITY DIAGRAM

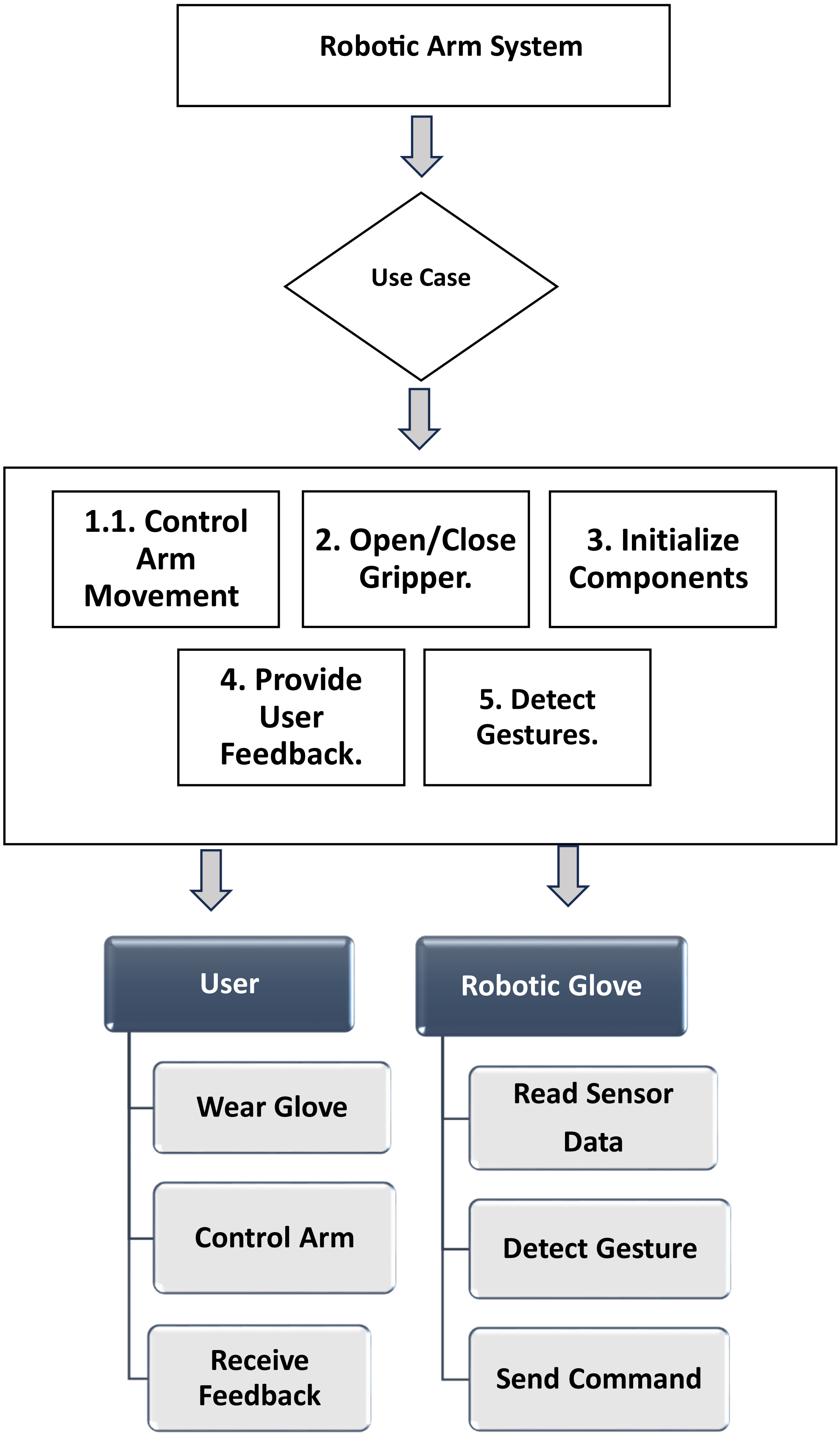


3.3 CLASS DIAGRAM

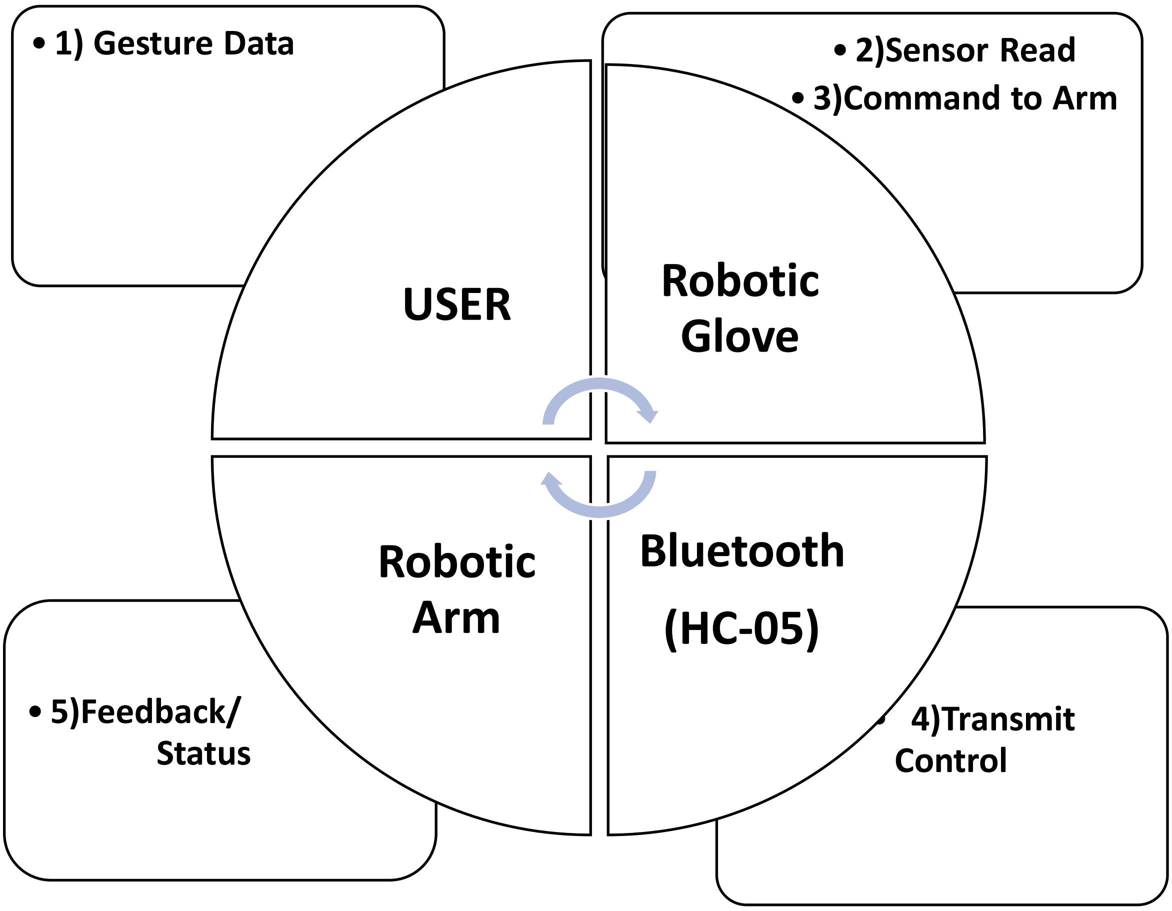


- **GestureSensor:** Captures gestures and sends data.
- **Arduino:** Processes gestures and converts them to commands.
- **Communication:** Transmits commands wirelessly.
- **RoboticArm:** Executes commands to move, grip, or release

3.4 USE-CASE DIAGRAM



3.5 DATA-FLOW DIAGRAM



CHAPTER 4

MODULES

Detailed Breakdown of Project Modules for the DIY Arduino Robot Arm

4.1 Mechanical Module

- **Robotic Arm Structure:**
  - **Components**: The arm consists of various 3D printed parts including the gripper, arm segments, base, and turntable.
  - **Design**: The design allows for six degrees of freedom (DOF) using joints powered by servo motors, facilitating a wide range of movements.
  - **Assembly**: Each part must be precisely assembled, ensuring all joints are aligned and can move freely.
- **Servo Motors:**
  - **Types:** MG966R servo motors for joints and NEMA 17 stepper motor for the base.
  - **Functionality:** Each servo motor controls a specific joint, enabling rotation and movement as dictated by the control signals from the Arduino.

4.2 Control Module

- **Microcontroller**:
  - **Arduino Uno**: It processes input from the sensors and sends commands to the servo motors.
  - **Programming**: The control logic is programmed using the Arduino IDE, incorporating libraries.

- **Servo Driver**:
  - **PCA9685**: This I2C servo driver enables control of up to 16 servo motors simultaneously, allowing for precise angle adjustments.
  - **Power Management:** The PCA9685 requires an external power source for the servos to ensure they operate reliably under load.

4.3 Sensor Module

- **Robotic Glove**:
  - **Flex Sensors:**
    - Detect the bending of fingers. Each sensor corresponds to finger, translating finger movements into electrical signals.
    - Flex sensors are connected to the Arduino Nano in the glove, allowing it to read the values and send commands.

- **MPU6050 Accelerometers:**
    - Measure the orientation and motion of the wrist. This data allows the robotic arm to mimic wrist movements.
    - The accelerometers communicate with the Arduino Nano to provide real-time feedback on arm position.

4.4 Communication Module

- **Bluetooth HC-05:**
    - **Role:** Enables wireless communication between the robotic glove (master) and the robotic arm (slave).
    - **Configuration:** The Bluetooth modules are set communicate at a baud rate of 4800, allowing for fast data transfer.
    - **Signal Transmission**: When the glove detects a gesture, it sends a corresponding signal to the robotic arm to execute the movement.

- **Arduino Nano:**
    - **Purpose**: Acts as the processor in the glove, reading sensor data and communicating with the arm via Bluetooth.

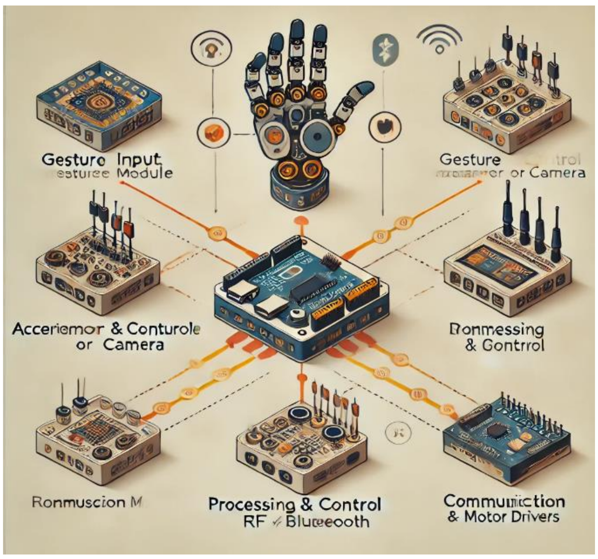
4.5 Power Supply Module

- **Battery Pack**:
    - **5V, 2200 mAh Battery**: Powers the Arduino Uno and servo motors.
    - **LiPo Battery (11.1V)**: Provides power to the NEMA 17 stepper motor, ensuring sufficient torque for base rotation.
    - **Power Distribution**: Proper wiring and power distribution are crucial to avoid brownouts or power loss during operation.

4.6 Programming Module

- **Arduino Code:**
  - **Functionality:** The code processes incoming data from the glove and controls the servo motors based on the mapped values.
  - **Key Features:**
    - **Sensor Reading:** Reads values from flex sensors and accelerometers to determine gestures.
    - **Motor Control**: Maps sensor readings to specific motor actions, using conditional statements to dictate movements.

- **Calibration Routines:**
  - **Purpose:** To ensure the system accurately responds to gestures, calibration routines are implemented.
  - **Process**: Users can reset and calibrate the sensors by pressing a button, allowing the system to adjust to varying user hand sizes and flex sensor sensitivity.



4.7 User Interface Module

- **LED Indicators:**
    - **Status Indication:** LEDs can be used to signal the operational status of the robotic arm, such as when it's receiving commands or executing movements.
- **User Manual/Guide:**
    - **Documentation:** Clear instructions on assembly, programming, and operation are crucial for users to understand how to use and troubleshoot the system.
    - **Support Resources:** Links to online forums, community contributions, and additional documentation can enhance user experience.

Integration and Interaction of Modules

Each module interacts seamlessly with others, creating a fully functional system. For example:

- The **Sensor Module** detects gestures and sends signals through the **Communication Module**.
- The **Control Module** processes these signals and sends commands to the motors via the **Power Supply Module**.
- The **Mechanical Module** executes movements based on the processed commands, bringing the robotic arm to life.

CHAPTER 5

SYSTEM REQUIREMENT

To build a DIY Arduino-based robotic arm controlled by hand gestures, you'll need a comprehensive system that includes the robotic arm components, robotic glove sensors, necessary electronics, and the programming setup. Below is a detailed breakdown of the system requirements:

5.1 Hardware Requirements

5.1.1 Mechanical Parts

- **3D Printed Robotic Arm Components** (credits to Thingiverse and Wonder Tiger):
  - Gripper Parts
  - Base and Turntable
  - Robotic Core Arm
  - NEMA 17 Stepper Motor for Base Rotation (for added stability and rotation)
  - Various Screws and Bolts.
- **Robotic Glove Parts**:
  - 3D Printed Exoskeleton Gauntlet or Standard Builder's Glove.
  - 3D Printed Sensor Holders for glove attachment.

5.1.2 Electronics for Robotic Arm

- **Arduino Uno –** Main microcontroller for the robotic arm.
- **MG996R Servo Motors (6 units) –** Controls various arm joints.
- **PCA9685 Servo Driver –** For driving multiple servos simultaneously.
- **Battery Pack (5V, 2200 mAh) –** Power supply for servo motors.
- **A4988 Stepper Motor Driver –** To control the NEMA 17 stepper motor for base rotation.
- **LiPo 11.1V, 2200mAh, 3s Battery** – Power source for NEMA 17 motor.
- **HC-05 Bluetooth Module –** For wireless communication between the glove and arm.
- **Breadboard and Jumper Wires –** For prototyping connections.

5.1.3 Electronics for Robotic Glove

- **Arduino Nano** – Main microcontroller for the glove.
- **HC-05 Bluetooth Module** – For transmitting data to the robotic arm.
- **Flex Sensors (3 units)** – Placed on the glove fingers to detect bending gestures.
- **MPU6050 Accelerometers (2 units)** – Detects wrist and arm movement (e.g., rotation).
- **Resistors (10K, 220R)** – Used to manage current for sensors and LEDs.
- **Capacitors (100nF)** – Used to stabilize the circuit.
- **9V Battery with Clip** – Power source for the Arduino Nano on the glove.
- **LED** – For visual feedback on the glove.
- **Braided Cable Sleeve** – To organize wires on the glove.

5.1.4 Programming and Software Requirements

- **Arduino IDE** – For programming both the Arduino Uno and Arduino Nano.
- **HCPCA9685 Library** – To control the servo motors via PCA9685.
- **Robotic Arm Code** – Controls the movement of each servo motor based on incoming data.
- **Robotic Glove Code** – Reads data from flex sensors and accelerometers, then sends data to the robotic arm.
- **Bluetooth Configuration** – Setting the HC-05 modules to Master (Glove) and Slave (Arm), with a baud rate of 4800.

5.1.5 Assembly Requirements

- **Wiring Diagram and Assembly Layout** – Plan for connecting each servo, stepper motor, and sensor to their respective controllers.
- **Soldering Iron & Tools** – To secure connections, especially on the glove.
- **Multimeter** – To check connections and troubleshoot as needed.

5.1.6 Functionality Testing and Calibration

- **Flex Sensor Calibration Code** – To determine the high and low resistance limits for each gesture.
- **MPU6050 Calibration** – Adjust the accelerometers to detect wrist and arm movement accurately.
- **Bluetooth Pairing Test** – Ensure communication between the glove and robotic arm works seamlessly

5.2 Software Requirements

1. **Arduino IDE**
    - To program the Arduino Uno and Nano microcontrollers.
2. **Arduino Libraries**
    - HCPCA9685 Library: Required for controlling servo motors via the PCA9685 module.
    - Wire.h and Adafruit_MPU6050: Required for accelerometer communication.
3. **Bluetooth Serial Communication**
    - Set up Bluetooth modules at 4800 baud rate for smooth data transmission.

5.2.1 3D Printing Requirements

1. **3D Printer**
    - Required to print the robotic arm parts.
2. **STL Files**
    - Download STL files for arm and glove from Thingiverse (Wonder Tiger for the arm and Roman13 for the glove).
3. **Printing Settings**
    - For larger hand sizes, print glove at 105% scale.
    - Arm components may take up to 40 hours of total print time.

5.2.2 Assembly and Testing Tools

1. **Screwdriver and Fasteners**
    - For assembling the robotic arm.
2. **Multimeter**
    - For testing circuits.
3. **Calibration Tools**
    - Required to calibrate sensors, especially flex sensors and accelerometers.
4. **Computer with USB Port**
    - For programming and interfacing with Arduino microcontrollers.

Each component above contributes to a responsive, programmable, and Bluetooth-controlled robotic arm with gesture control capabilities, suitable for DIY and experimentation. Let me know if you'd like further detail on a specific component or assembly step.

CHAPTER 6

CONCLUSION & REMARK

The application of robot arms controlled by human gestures has the potential to revolutionize various sectors, including healthcare, education, and assistive technologies. Beyond these fields, gesture-controlled can perform tasks in hazardous environments, and in daily life, assisting individuals performing everyday tasks and basic activities.

Ultimately, gesture-controlled robot arms are accuracy, safety, and latency, ongoing advancements in sensor technology, artificial intelligence, and gesture recognition technology across multiple industries.

REFERENCES

[1] Prathibha Kiran, Jagadeesha S, Sonu S, Priyanka N, Mohammed Shahid, and Syed Suleiman Kaleem, "Design and Development of Gesture Controlled Robotic Arm," *International Journal of Computer Applications Technology and Research*, vol. 13, no. 5, pp. 8–11, 2024. DOI: 10.7753/IJCATR1305.1002.

[2] R. Khan, M. M. U. Saleheen, and M. R. Fahad, "Gesture-Controlled Robotic Arm," in *Proc. 2023 International Conference on Computer Science and Information Technology (ICCoSITE)*, Feb. 2023. DOI: 10.1109/ICCoSITE57641.2023.10127689.

[3] P. J. Ezigbo, O. C. Nosiri, E. S. Mbonu, V. Ofor, and J. Obichere, "Hand Gesture Recognition and Control for Human-Robot Interaction Using Deep Learning," *International Journal of Electrical and Electronic Engineering & Telecommunications*, vol. 12, no. 6, pp. 433-441, Nov. 2023. DOI: 10.18178/ijeetc.12.6.433-441.

[4] Dr. Katherasan Duraisamy, Lenin. S. A, Rahul. S, Reshma. R, Sanjay. C (May 2022) Gesture Controlled Robotics Hand International Journal of Advanced Research in Science, Communication and Technology (IJARSCT).

[5] N Nissi Kumar et al 2022 J. Phys.: Conf. Ser. 2325 012012 Robot ARM with Gesture Control International Conference on Electronic Circuits and Signalling Technologies 2325 (2022) 012012.

[6] Wu, X. H., Su, M. C., & Wang, P. C. (2010, October). A hand-gesture-based control interface for a car-robot. In 2010 IEEE/RSJ International Conference on Intelligent Robots and Systems (pp. 4644-4648). IEEE.

[7] Chanhan, G., & Chandhari, P. (2015, November). Gestures based wireless robotic control using image processing. In 2015 5th Nirma University International Conference on Engineering (NUiCONE) (pp. 1-7). IEEE.

[8] Root, K., & Urniezius, R. (2016, September). Research and development of a gesture-controlled robot manipulator system. In 2016 IEEE International Conference on Multisensor Fusion and Integration for Intelligent Systems (MFI) (pp. 353-358). IEEE.

[9] Mendes, N., Ferrer, J., Vitorino, J., Safeea, M., & Neto, P. (2017). Human behavior and hand gesture classification for smart human-robot interaction. Procedia Manufacturing, 11, 91-98.

[10] Zaman, H. U., Joy, A. A., Akash, K. M., & Fayad, S. T. (2017, June). A simple and effective way of controlling a robot by hand gesture. In 2017 International Conference on Intelligent Computing and Control Systems (ICICCS) (pp. 330-333). IEEE.

[11] Raheja, J. L., Chandra, M., & Chaudhary, A. (2018). 3D gesture based real-time object selection and recognition. Pattern Recognition Letters, 115, 14-19.

[12] Ahmed, S., Popov, V., Topalov, A., & Shakev, N. (2019). Hand Gesture based Concept of Human-Mobile Robot Interaction with Leap Motion Sensor. IFAC-PapersOnLine, 52(25), 321-326.

[13] Li, X. (2020). Human–robot interaction based on gesture and movement recognition. Signal Processing: Image Communication, 81, 115686.

[14] Vignesh, T., Nivetha, R., Mowneka, G., & Selvakumar, D. (2019, March). Design and Fabrication of 6-axis Gesture Controlled Robot. In 2019 5th International Conference on Advanced Computing & Communication Systems (ICACCS) (pp. 246-250). IEEE.

[15] M. Ramkumar and Vijay Ananad, "ECG Cardiac arrhythmias Classification using DWT ICA and MLP Neural Networks", Journal of Physics Conference Series, vol. 1831, pp. 1-13, Mar. 2021.

[16] AB. Yildiz, "Electrical equivalent circuit based modeling and analysis of direct current motors", Electrical Power and Energy Systems 2012, vol. 43, pp. 1043-1047.

[17] H. He and Y. Dan, "The research and design of Smart mobile robotic arm based on gesture controlled", 2020 International Conference on Advanced Mechatronic Systems (ICAMechS), pp. 308-312, 2020.

[18] S. Bularka, R. Szabo, M. Otesteanu and M. Babaita, "Robotic Arm Control with Hand Movement Gestures", 2018 41st International Conference on Telecommunications and Signal Processing (TSP), pp. 1-5, 2018.

[19] B. Schabron, Z. Alashqar, N. Fuhrman, K. Jibbe and J. Desai, "Artificial Neural Network to Detect Human Hand Gestures for a Robotic Arm Control", 2019 41st Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), pp. 1662-1665, 2019.

[20] R. V. Dharaskar et al., "Robotic Arm Control Using Gesture and Voice", Int. Journal of Computer Inf. Technology & Bioinformatics (IJCITB)., vol. 1, no. 1, 2012, ISSN 2278-7593.