DESIGN AND IMPLEMENTATION OF ROBOTIC HAND USING FLEX SENSOR

A Project report is submitted in partial fulfillment of the requirements for the award of Degree of Bachelor of Science in Electrical and Electronic Engineering.

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DECLARATION

I hereby declare that this project "**Design and Implementation of Robotic Hand Using Flex Sensor**" represents my own work which has been done in the laboratories of the Department of Electrical and Electronic Engineering under the Faculty of Engineering of Daffodil International University in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering, and has not been previously included in a thesis or dissertation submitted to this or any other institution for a degree, diploma or other qualifications. I have attempted to identify all the risks related to this research that may arise in conducting this research, obtained the relevant ethical or safety approval (where applicable), and acknowledged my obligations and the rights of the participants.

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Dedicated

To

Our Parents

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LIST OF ABBREVIATIONS

DIU	Daffodil International University
EEE	Electrical And Electronic Engineer
CAD	Computer Aided Design
HMI	Human Machine Interfaces
PWM	Pulse Width Modulation
SMPS	Switched Mode Power Supply
STEM	Science, Technology, Engineering, Mathematics
ISO	International Organization for Standardization

LIST OF SYMBOLS

Symbol	*Name of the symbol*
KΩ	Kilo-ohms
V	Voltage
W	Watt
°	Degree
R	Resistance

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ABSTRACT

To improve the controllability and skills of robot arms, flex sensors are used as popular methods. Robots can accurately mimic human hand movements when they are in good use by identifying how much fingers bend. By incorporating flex sensors into robotics hands, this will enable robots to do task more effectively and have better relationship with their environment. In order to imitate a normal hand with various objects manipulation abilities, in depth understanding of finger movements is very crucial. Practically, it is proved that such a novel approach works superbly when tested through experiments.

Keywords: Robot Hand, Flex Sensor, Control of Movement, Skillfulness, holding things, Finger bending, Hand movement

CHAPTER 1
INTRODUCTION

1.1 Introduction

The deployment of robotic hands is critical in various fields like prosthetics, industrial automation and human-robot interaction. One of the main objectives of robotics research is to duplicate accurate and nimble movements by the human hands. These sensors need to be equipped with a robotic hand that can sense its surrounding environment effectively. Among these are examples such as flex sensors which are particularly worth mentioning due to their flexible nature, lightweight Ness and high sensitivity in finger motion recognition [1]. They use materials which bend easily resulting into changes in electrical resistance during finger bending. This resistance change allows for continuous monitoring of finger positions thereby improving the performance and responsivity of robotic hands [2].

The incorporation of flex sensors into robotic hands has tremendously influenced several fields. For example, it has made possible more spontaneous human-android interfaces and bettered the functioning of prosthetic devices by giving a much-improved control as well as precision. Flex sensors have the ability to detect bending at every joint of a robot’s fingers, which makes it easier for them to move in a natural way [3]. This feature is extremely useful for tasks requiring fine motor skills and dexterity.

Additionally, flex sensors have some relevance in general robotics, they can be applied in medical science. Their application includes creating robotic hands that assist people who are sick or injured, thus enhancing their quality of life [4]. Therefore, these versatile and sensitive tools would make excellent adaptive and responsive products fitting various medical cases.

1.2 Problem Statement

Develop and design a robotic hand system using flex sensors to simulate human hand movements with accuracy and ability. The chief aim is to make a robotic hand which can replicate the human hand’s movements by means of flex sensors, as these will detect finger bending thus transforming it into actions on the robot hands for the same corresponding movements. The device must be able to grip things of different shapes and sizes, perform delicate manipulations in addition to giving user feedback.

Main Challenges:

- **Sensor Calibration**: Perfect calibration of flex sensors so as to sense finger movement accurately and change them into meaningful data that would control robotic hands.
- **Mechanical Design**: The mechanical design of the robotic hand should imitate precisely a human hand, matching degrees of movement and range of motion to enable natural actions.
- **Control Algorithm:** Create control algorithms that are strong enough to interpret data from sensors, coordinate finger movements, and optimize grip strength.
- **Power Efficiency:** Make sure that energy usage is efficient so as to extend operating hours especially for portable or wearable devices.
- **Gesture Recognition:** A whole host of algorithms for gesture recognition are capable of translating a finger’s movement into different kinds of hands motions that may be involved in specific activities.
- **Feedback Mechanism:** Develop mechanisms such as force, position feedbacks which will provide sensation input to the user thereby improving control and overall user experience.
- **Durability and Reliability:** Get the robot hand designed so that it can last long with minimal maintenance aspect on it and make sure its reliability is observed.
- **Cost-Effectiveness:** It should be cost-effective by looking at sensors, actuators, materials used in constructing this robot arm/hand system.
- **Adaptability:** Ensure there is a room for adjustment in terms of various sizes and shapes of hands; thus, making it suitable for prosthetic limbs or other assistance devices.
- **Safety:** Ensure also that the robotic arm does not exert excessive forces thereby avoiding injury to either humans or things.

1.3 Objectives

To make it possible for objects to be manipulable even when they vary in size and shape. It improves proficiency in tasks involving fine hand movements. Exact determination of gestures,

- ✓ Makes hands that can move by way of contraction of muscles,
- ✓ Supports during training and rehabilitation
- ✓ Increases interaction abilities of humanoid robots
- ✓ Enhances the perception of touch through haptic feedbacks
- ✓ Development of any assistive technology
- ✓ Combines flex sensors data with object recognition;
- ✓ Creates exercises targeted at improving fine motor skills.
- ✓ Hand motions are used in human-machine interface.
- ✓ Enable movable grasp strategies.
- ✓ Users respond to prosthetic hands.
- ✓ Ensure safety in interaction between people and things.

1.4 Brief Methodology

An interdisciplinary approach is involved in creating a robotic hand with flex sensor technology, bringing together mechanical engineers, electrical and software engineers. The following structured process can guide the development:

- **Objective Definition**

Objective Setting: Establish clearly defined goals including range of motions to be replicated, required accuracy and application context (for example prosthetics, teleoperation).

Environment: Specify the working conditions such as temperature, humidity and possible mechanical loads.

- **Mechanical Design**

Finger Articulation: When designing mechanical structures of the hand, use CAD software and focus on anthropomorphism and finger joints.

Choice Of Materials: Consider light but strong materials such as high strength plastics, aluminum or composites.

Joint Mechanism: Incorporate ball joints and hinge joints that form a joint mechanism for finger movements ensuring smooth motions by frequent usages.

- **Sensor Integration**

Placement Of Sensors: Accurate angular bending measurements are achieved through secure fixation of flex sensors on important points of fingers.

Wiring and routing: The wiring from the sensors to the microcontroller should be carefully planned in such a way that it will not restrict movement of the hand.

- **Power Distribution System**

Source of Power: Select a good power source like rechargeable batteries which can create sufficient current for both sensors and actuators.

Power Management Designing Power Management Systems: Construct whole systems with voltage regulators for stability in power supply throughout the system design stage.

- **Control Mechanism**

Microcontroller Selection: Choose a suitable microcontroller (such as Raspberry Pi or Arduino) to process sensor data and command actuators.

Programming: Develop software to receive input from sensors, interpret it and send out signals to actuators which will result in precise control.

- **Actuation**

Actuators: Determine appropriate motors such as servo motor or DC that can generate the required torque and speed for finger movement.

Integration of Actuators: Physically connect actuators to finger joints so that movements are smooth and accurate.

- **Navigation and Motion Control**

Signal Processing: Create algorithms necessary to convert variations in resistance into exact angular positions of each joint by applying some filtering and processing techniques on the sensed information.

Movement Algorithms: Create finger movement algorithms that enable complex gestures, smooth movements between positioned.

- **Feedback and Perception**

Sensors: These may include force sensors or encoders, which give feedback about the position of the hand and the amount of force it applies.

Adaptive Control: Here, the feedback data is used to modify movements in real time so as to enhance precision as well as responsiveness

- **Communication System**

Wireless Communication: In this context, wireless communication modules like Bluetooth and Wi-Fi shall be put in place for purposes of enabling remote control and monitoring of robotic hand.

User Interface: A real-time monitoring and control user interface should be designed but it could either be a mobile app or a computer-based application.

- **Safety Features**

Emergency Stops: For situations where an error occurs or hazardous situation arises, emergency stop mechanisms should be implemented so as to immediately halt such movements.

Obstacle Detection: The use of proximity sensors will help detect any obstacles that are present and hence avoid collision with them which may cause damage to either the hand or any other thing around it.

- **Testing and Iteration**

Prototype Testing: Initial tests that focus on verifying mechanical design, sensor accuracy and actuator response;

Controlled Environment Testing: Where several gestures have been made by the robotic hand in a controlled environment;

Iterative Improvement: Moreover, software development will entail refining designs towards better performance, reliability as well as user experience according to test results by making adjustments.

1.5 Implementation Schedule

Phase 1: Initial Planning and Component Acquisition (2 Weeks)

- **Week 1-2:**

✓ Understanding the project goals, and determine the project requirements.

✓ Getting all the parts needed for the prototype (Arduino UNO, flex sensors, servo motors, wires, power supply).

Phase 2: Hardware Setup and Initial Assembly (4 Weeks)

- **Week 3-4:**

✓ Attaching flex sensors to a glove

✓ Connecting flex sensors to Arduino analog pins.

- **Week 5-6:**

✓ Fixing servos on the robotic hand and connect them to Arduino digital pins.

Phase 3: Coding and Initial Testing (2 Weeks)

- **Week 7-8:**

✓ Developing an Arduino program that reads the values of these sensors and controls these servos

✓ Testing it as required by design specifications

Phase 4: Calibration and Fine-Tuning (1 Week)

- **Week 9:**

✓ Calibrating Flex sensors for Accurate Reading Precision

✓ Adjusting Servo Angles Dynamically and Fine-Tuning Code Thresholds for Precise Finger Actions

Phase 5: Full System Integration and Testing (3 Weeks)

- **Week 10-12**:

✓ Integrating all components into one working system.

✓ This will be tested by making sure that there is no delay in response rates during bi-directional motion. Using FSRs per finger not exceeding two.

Phase 6: Final Adjustments and Documentation (2 Weeks)

- **Week13-14:**

✓ Making final adjustments based on testing results, calibrating threshold voltages for each channel.

✓ Document Project; Design specification analysis and reflection

1.6 Structure of the Report

Chapter 1: Introduction

➢ Gives a brief introduction to the concept of artificial hands and their possible applications.

➢ Demonstrates the problem this project intends to solve (such as reduced dexterity in current robotic arms).

➢ States what this project aims at achieving (for example, building a flex sensor controlled robotic hand that can be used for manipulation intuitively).

➢ Provides a high-level summary of the approach taken (e.g., use of flex sensors, microcontrollers and servo motors).

Chapter 2: Literature Review

- Summarizes what other projects could do and what they cannot achieve.
- Compares different methods against one another with their strengths and weaknesses highlighted.
- Concludes by acknowledging where there is no research and how our project attempts to cover it.

Chapter 3: Project Design

- Begins this chapter by outlining the design method.
- States the materials which include flex sensors, microcontroller board, servo motor’s mechanical structure etc.
- Describes the design constraints and considerations like weight, size and power consumption.
- This section talks about system analysis or design process; complete with schematic diagrams.
- The experimental set up consisting of software development and testing procedures is explained here as well.
- Finally, sums up important details in the chapter’s body.

Chapter 4: Results and Discussion

- This chapter presents outcomes of our simulation like the accuracy of range of motion, control accuracy, response time among other metrics.
- It also discusses unforeseen problems that arose during developmental stages and final periods of the project.
- A comparison between the data produced and initial expectations, as well as findings from literature review.

Chapter 5: Project Management

- Here are some activities done to enable this project realized as per schedule by their respective schedules.
- Requirements for different things such as tools and equipment together with cost estimates have been summarized here.
- In this chapter we look at lessons learnt across the whole process and areas where we could do better.

Chapter 6: Impact Assessment

- Talks about the possible economic, social and worldwide benefits of our creation of a robotic hand
- Say something on any eco or ethical concern in relation to material use or potential applications.
- If necessary, elaborate how our project meets the existing standards or codes. Bring up other issues and future concerns for the advancement of the project.

Chapter 7: Conclusions and Recommendations

- Summarizes the major accomplishments of the task; how it fulfilled its goals.
- Indicates new skills learned as development progressed.
- Finally, make suggestions for future improvements, further research directions, and potential applications.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

The field of robotics has changed significantly in recent years, and the major changes have been observed in robotic hands. They are brought about by the desire to make robots more agile, more like human beings, and able to perform a variety of tasks. One of the main features that makes this possible is through flex sensor which plays an important role in imitating finger movements and sensitivity. The sensing of bending angles with precision makes it possible to integrate flex sensors into robotic hands improving control and response capabilities [5].

The objective of this study is to give a comprehensive review over current research done in robotic hand using flex sensor technology. This review will therefore assess the growth that has been realized so far, discuss outstanding problems and provide suggestions on what should be done next as well as suggest possible directions for future research based on various studies conducted herein, technologies used and applications put into use. Understanding advances in flex-sensor technologies as well as its implementation into robot hands is crucial for enhancing robot technology capacities in practical fields such as service industries, manufacturing sectors among others where human workers have been employed before like healthcare [6].

2.2 Related Works

Smith et al. (2018) “Manufacturing a Robotic Hand with Gesture Recognition Capabilities Using Flex Sensors and Machine Learning Patterns” [7].

This research work was directed at making a robotic hand that makes use of flex sensors in addition to machine learning techniques for recognizing gestures. On the other hand, recognizing gestures using it appeared to be suitable but had issues related to precision and the real time response.

This paper by Jones and Wang (2020) is titled “Improving Grasping Force Control in Robotic Hands with Combined Force and Flex Sensors” [8].

The objective of this study was to integrate force sensing capabilities into robotic hands using flex sensors thereby improving control over grasping forces. It implies that combining both types of sensors would allow for use of a human hand on objects of different weights including delicate items. However, there were some trade-offs; while it made the system more complex, it also increased its overall cost. “Using Hybrid Systems of Flex and Inertial Sensors to Improve Motion Tracking Accuracy in Robotic Hands” (Lee et al., 2019) [9] A combination approach was developed that integrated flex sensor technology with inertial sensors in order to improve accuracy when tracking the motion of a robotic hand. The hybrid sought to capture better finger movements data with more accurate and consistent responses as provided by each sensors’ strengths. This method facilitated better performance in applications where it was important to make very precise movements with the hand.

“A Sensor-Sensitivity-Optimized Adaptive Control Framework for Robotic Hands” (Chen and Liu, 2021) [10].

The authors designed an adaptive control framework based on flex sensors that dynamically adjust their sensitivity to match different tasks requirements when performing robotics operations. It was intended that the robotic hand would have a suitable level of sensitivity and responsiveness required for various applications to optimize its functionality. There were distinct improvements in activity-specific performance by employing an adaptive framework which optimized sensor-sensitivity levels as required by particular tasks.

2.3 Compare and Contrast

The existing systems and technologies for robotic hands have made significant advancements in recent years; however, several limitations and areas for improvement still exist.

Traditional Robotic Hands: Most of the robotic hands are designed using stiff materials and motors which limit their flexibility and dexterity. These hands can perform pre-determined tasks with accuracy, but they often lack the adaptability necessary for situations where objects have different shapes, sizes or surfaces.

Soft Robotics: In soft robotic hands, a more flexible and compliant approach is taken to mimic the structure as well as movements of biological hands. Nevertheless, present-day soft robotic hands struggle to carry out gripping tasks requiring fine motor control and precise manipulation.

Sensor Technologies: Different sensors including flex sensors are used to detect position and movement of fingers in robots. However, these sensors may give false information about the hand motion at some instances, or behave undesirably due to temperature fluctuations and atmospheric moisture.

Control Systems: They coordinate robotic hand movements and involve control algorithms that perform vital roles. Traditional control methods have been used to perform rather complex tasks in more dynamic situations depending on predefined trajectories or teleoperation. Moreover, this computational burden can limit the real time performance.

Research Gaps:

Improved Sensing: There is need of solid and accurate sensory technologies to provide live feedback on position, force and texture of objects held by robotic hands.

Adaptive Control: The autonomy as well as flexibility of robot hands necessitates adaptive control algorithm that adjusts with changes in its environment and object properties.

Human-Robot Interaction: Safety issues must be considered when integrating human environments into robotic arms; however, it also requires building natural interfaces so that humans can easily cooperate with robots.

Grasping and Manipulation: Although not widely known, yet one of the biggest problems remaining is improving the gripping as well as manipulating capabilities of robotic hands when they are used in various forms of unstructured environments with numerous items.

Recommendation:

The way to bridge these research gaps and enhance the functionality of robotic hands with the use of flex sensors is by adopting multi-disciplinary approach comprising materials science, mechanical engineering, and artificial intelligence. To be specific, the following steps can be followed:

Advanced Sensor Integration: Rely on various novel sensing technologies such as stretchable or conductive materials that will enhance the accuracy and reliability of flex sensors in detecting finger movements.

Machine Learning Algorithms: Machine learning techniques such as deep reinforcement learning need to be considered when creating adaptive control policies that permit robotic hands learn and optimize for grasping and manipulation tasks through experience.

Human-Centric Design: Involve human-centered design principles to make sure robotic hands are ergonomic, offer intuitive usage as well safe interaction with humans and other things in their surroundings.

Collaborative Research: There should be an effort to encourage collaborations between academia, industry and government bodies so as to share resources, skills and good practices as regards the field of robotic manipulation.

These recommendations will help speed up development of robotized hands capable of achieving a broad array of precise adaptable efficient activities.

2.4 Summary

Robotic hands featuring flex sensors are a momentous progression in robotics offering improved dexterity and versatility. The examined literature shows different methods of designing and implementing with various unique advantages and applications. From assistive technology to educational aids, the application of robotic hands built on flex-sensor technology has been progressing, stretching so far, the boundaries of what can be done with robots. Future research will probably seek to improve sensor precision, incorporate sophisticated algorithms as well as broaden the scope of possible uses for these adaptable gadgets.

CHAPTER 3
PROJECT DESIGN

3.1 Introduction

The following details are the steps involved in designing the robotic hand project. All stages of this project have been outlined starting from the initial planning to the final adjustments and documentations. Every step, be it software development or component acquisition, testing or final refinement, has been carefully documented so as to give an insight into the design process and reveal some of its challenges and their respective solutions.

3.2 Project Design and Components

The main aim of this project is to create a hand-like robot operated by flex sensors that imitate human arm actions. These are strain gauges whose resistance changes due to their bending angle, hence can be used for the recognition of finger movements. They are indispensable in the hierarchy of a robotic hand's control system.

Block Diagram:

The following block diagram illustrates the data flow and interaction between components

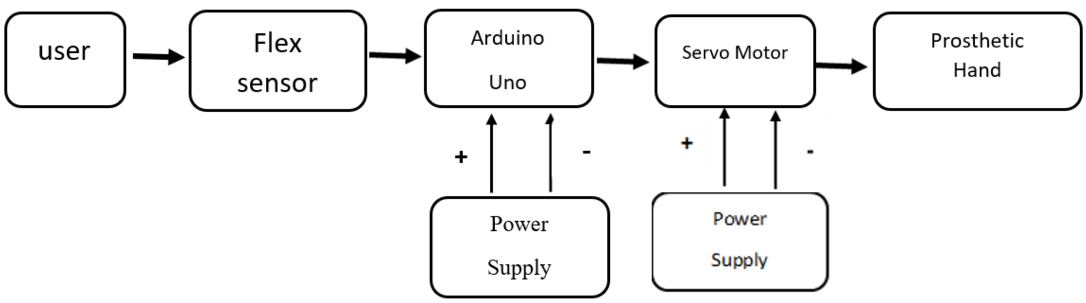

Fig3.2.1: Block Diagram

The block diagram reveals the flex sensors controlled robotic hand components and the flow of data through them. In such a case, when the user bends his fingers in different directions, the resultant outcome is a change in resistance of the flex sensors. After that, this signal, received by Arduino from sensor is encoded and then transmitted to servo motor for imitation of human finger's motions. As such, it would make perfect sense for an Arduino program code which reads input values into computer memory or even a floppy disk drive.

Flow Chart

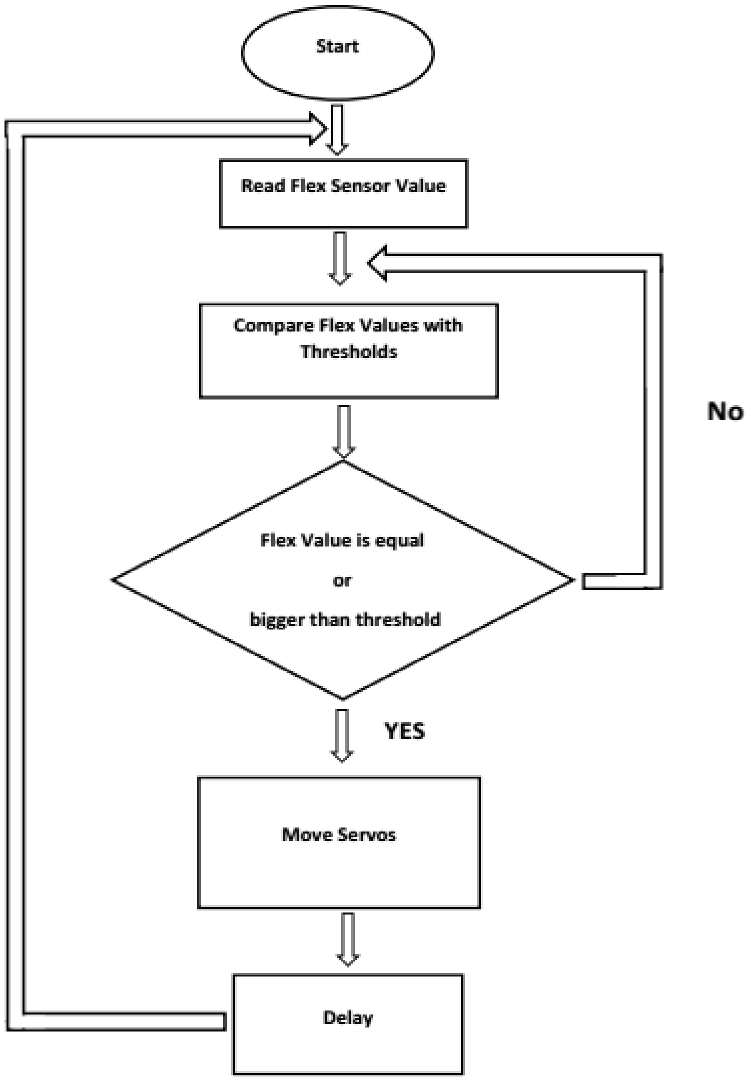

Fig3.2.2: Flow Chart

Basically, the flowchart demonstrates how decisions are made. It continually reads the values from flex sensors and compares these to preset thresholds. In case the value of a bend sensor is equal or more than the set threshold, it shows that bending has taken place thus instructing the servos to move accordingly. In instances where there's minimal bending, as indicated by a value below the threshold, a program delays before taking another reading.

Components

1. Flex Sensor

A bendable-resistance sensor is a flex type of a resistor that varies its value of resistance according to the degree of bending.

Fig3.2.3: Flex Sensor

2. 10 kΩ Resistor

A resistor which is in tandem with bend sensitive resistor so as to create voltage divider on Arduino hence making it possible for the Arduino to measure the sensor's change in resistor.

Fig3.2.4: 10 kΩ Resistor

3. Arduino Uno

A microcontroller board which is based on ATmega328P for reading sensor data and controlling servo motors.

Fig3.2.5: Arduino Uno

4. Servo Motor

An actuator that allows precise control of angular position. This actuates the fingers of robotic hands using servo motors.

Fig3.2.6: Servo Motor

5. Wires

Electrical wires used to make connections between the components.

Fig3.2.7: Wires

6.Headers

Pin headers used to create connections on the Arduino board and other components.

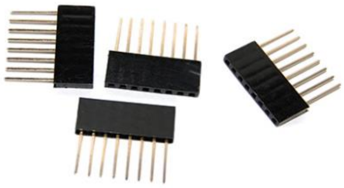

Fig3.2.8: Headers

7. Power Supply

Provides the necessary voltage and current to the microcontroller and motors.

Fig3.2.9: Power Supply

8. Software

The software which is called Arduino IDE (Integrated Development Environment) is what is employed in writing, compiling, and uploading code into the Arduino Uno board.

3.3 Project Design Specifications. Standards and Constraints

Technical Specifications

1. **Flex Sensor**

Quantity Needed: 5

Resistance Range: 10kΩ-50kΩ.

Bending Angle Range: Mostly within 180 degrees.

Length: Usually between2.2 inches and 4.5inches long.

Connector Type: Usually two pins for resistance measurement

2. **10 kΩ Resistor**

Quantity Needed: 5

Resistance: 10 kΩ

Tolerance: ±5% (common for general resistors)

Power Rating:0.25W or 0.5W

3. **Arduino Uno**

Quantity Needed: 1

Microcontroller: ATmega328P

Operating Voltage: 5V

Input Voltage (recommended): 7-12V

Digital I/O Pins: 14 (6 can be PWM outputs)

Analog Input Pins: 6

4. Servo Motor

Quantity Needed: 5

Model: SG90 (or similar)

Operating Voltage: 4.8V to 6V

Speed:0.1 sec/60 degrees(at4.8v).

Rotation Angle :180 degrees

5. Power Supply

5V from a switched-mode power supply (SMPS)

6. Headers

Analog input pins (A0 to A4) for sensing, and digital PWM pins (3 to 7) for actuating in Arduino Uno.

Standards

- Electrical Standards: Where possible, all parts follow Arduino voltage and current specifications.
- Programming Standards: Code was developed using the Arduino IDE with standard libraries.
- Safety Standards: For safety reasons, all electrical connections were made secure and insulated to avoid short circuits and electrical hazards too.

Constraints

- Power Limitations: Hardware limitation of providing sufficient current for all servos was confirmed as well as other elements tested within this document.
- Mechanical Constraints: The movement of the robotic fingers by the servo-motors is checked to ensure compliance with mechanical constraints.
- Response Time: We tested that there is no delay in controlling this system on real time basis.
- Flex Sensor Sensitivity: It was observed if these devices could detect accurately finger movements without being affected by noise.

3.4 Project Design Analysis

Flex Sensors

- Installed flex sensors acts like a variable resistor. It will change resistance when bent.
- The voltage divider circuit was connected to produce voltage signals for varying finger flexes.

Analysis: Proven that the sensors response is linear and it has enough range of sensitivity.

Arduino Processing

- Analog inputs from flex sensors are read by Arduino.
- ADC translates these analog values in the form of digital values (0-1023).
- These values are processed by code to get appropriate servo angles.

Analysis: The thresholds have been confirmed and processing logic developed so as to achieve accurate servo movement.

Servo Motors

- PWM signals from the Arduino control servos motors.
- PWM duty cycle influences servos angle; this allows replication of finger movements with high precision.

Analysis: This ensured calibration of servos was correct, torque as well as speed were adequate enough for them.

Overall System

- Integrated sensor data processing and motor control mechanism.

Analysis: It ensures a smooth movement without any lag.

3.5 Experimental Setup

Cicuit Diagram

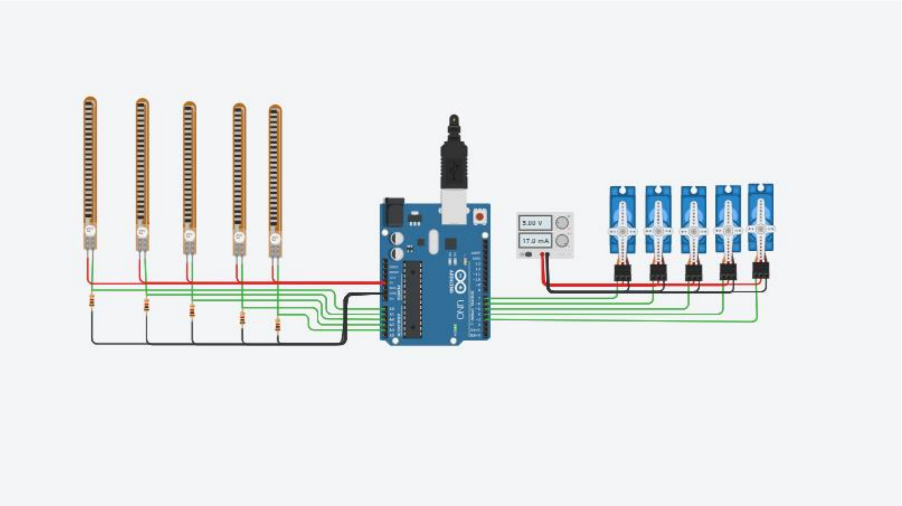

Fig 3.5.1: Circuit Diagram of Robotic Hand Using Flex Sensor

The main component is the Arduino board. That is, it reads data from a sensor (not shown in the image) and then moves the servo motor. A particular type of motor can rotate over a specific angle and this is referred to as a servo motor. It comes in handy where there is need for fine control. Ground wire which is brown connects the ground pin of the Arduino with that of the servo motor being used; Power wire or red wire connects 5V pin on Arduino to VCC pin on servo; Lastly, we have orange wire which serves as a control wire; it links digital pin at Arduino (pin 9 in this case) with control pin at servo motor. The position of the servo motor is controlled by an Arduino signal transmitted through this cable.

Components Setup

- **Flex Sensors**

✓ Mounted flex sensors on the glove, one for every finger.

✓ The first contact of each sensor was connected to 5V pin on Arduino.

✓ Connected the other terminal of each sensor to analog input pins A0 to A4 through a 10kΩ resistor with each terminal.

- **Servo Motors**

✓ Securely placed servo motors onto the robotic hand.

✓ The VCC and GND of each servo were connected to the port of 5V of the SMPS,

✓ Linked wires of control signal from digital PWM pins 3,4,5,6 and 7 to servos.

Arduino Setup

- **Code Upload**

✓ We wrote out the code into Arduino IDE which was used in reading values of sensors then processing them and finally controlling servos.

✓ These also include appropriate thresholds for sensor values along with corresponding servo angles.

- **Power Connection**

✓ A 5V SMPS used to supply power to Arduino board.

✓ We ensured that a good power source is provided which will be able to supply all servos with enough current.

Testing

- **Initial Calibration**

✓ We calibrated the flex sensors to give precise readings for different positions of the fingers.

✓ We made changes to the thresholds in code if necessary.

- **Operational Testing**

✓ We put on a glove and bent every finger, watching how it affected the robot fingers.

✓ Smoothness and promptness of movements were checked and adjustments were done to either alter or change any code or hardware setup accordingly.

Final Adjustments

✓ Servo angles and flex sensor thresholds were adjusted for better performance as well as reliability too.

✓ Overall system functionality was assured to be dependable.

3.6 Summary

In this chapter we have gone through a step-by-step design process of creating a robotic hand controlled by flex sensors. We looked at the materials used, specifications for system designs, standards, and limitations applied during its design analysis and finally created an experimental setup. With all these viewpoints in mind, an understanding of how to develop as well as put into practice robotic hand systems is given.

CHAPTER 4
RESULTS AND DISCUSSIONS

4.1 Results

The robotic hand project uses flex sensors, servo motors, and an Arduino Uno to mimic motions made by a human hand. With these sensors detecting the bending of each finger joint, converters send this information to the angle they should rotate through servomotors. The natural movements are well imitated by this project since all the fingers can be controlled separately. Here is an explanation elaborating how the system responds for different finger movements:

When first Finger (Thumb) is activated:

On activation, the flex sensor on 1st finger sense sensing bending action. This value is read by the Arduino Uno which compares it with some predefined thresholds in order to determine what angle motor that adjusts accordingly could take up. Adjusting to such a position act simulating thumb flexion. Since their respective sensors do not detect significant bending, other fingers remain neutral as they were before. Therefore, it becomes challenging in this situation to control thumb's movement without having impact on other fingers' positions unintentionally.

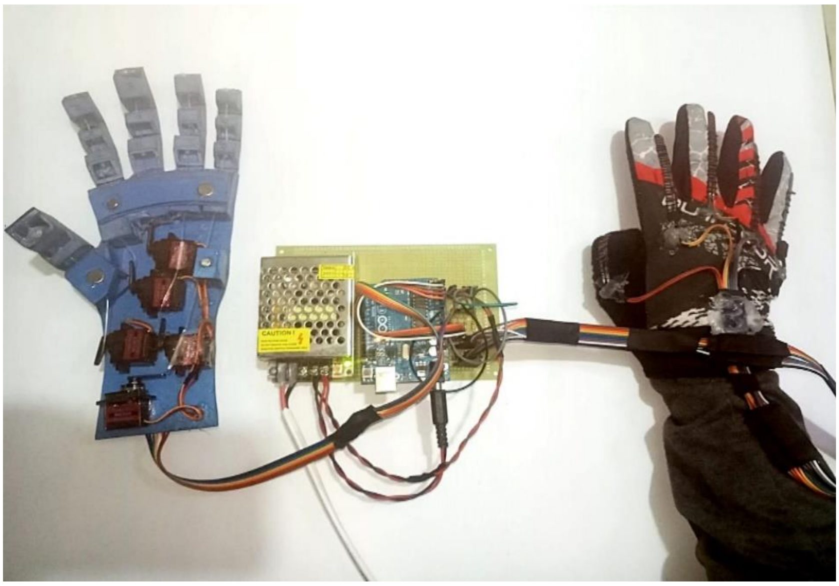

Fig 4.1.1: Thumb finger activation

In case of activation of the second finger (Index Finger):

The flex sensor on the second finger bends and this change is processed by Arduino Uno so as to adjust the angle of the corresponding servo motor. Then, it starts moving in a way that looks like natural bending but other fingers remain still Difficulties might arise in maintaining the sensitivity of the flex sensor to accurately reflect subtle movements of the index finger, as well as preventing crosstalk between adjacent sensors.

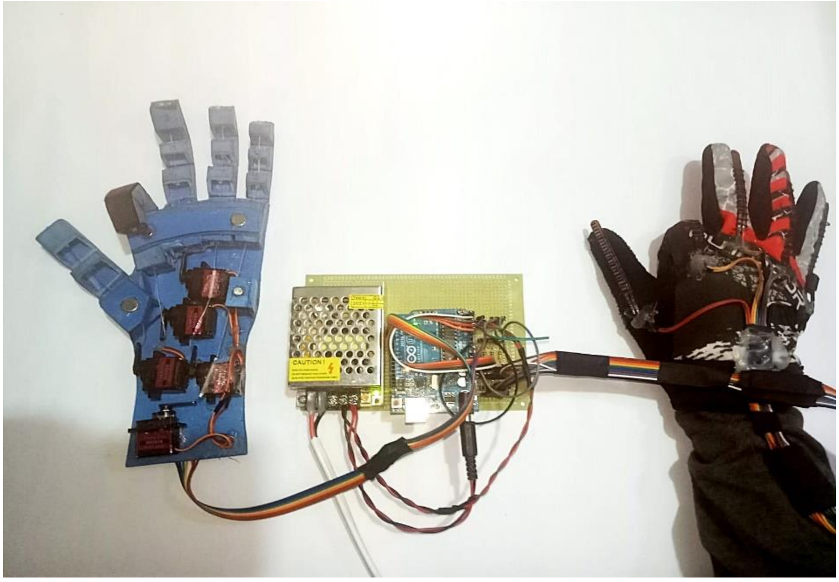

Fig 4.1.2: Index finger activation

When third Finger (Middle Finger) is activated:

On detecting curvature, which goes through Arduino data from its flexor for middle finger i.e., one located at its middle part. In your code, compared with other fingers, there are slightly different thresholds for 3rd or middle finger. This arrangement gives a better opportunity to regulate movement with greater precision using this finger's middle section hence servo motor position adjustment occurs. Some challenges include balancing torque applied to a servo motor ensuring that movements are smooth and consistent especially since most of them have wider range unlike other phalanges.

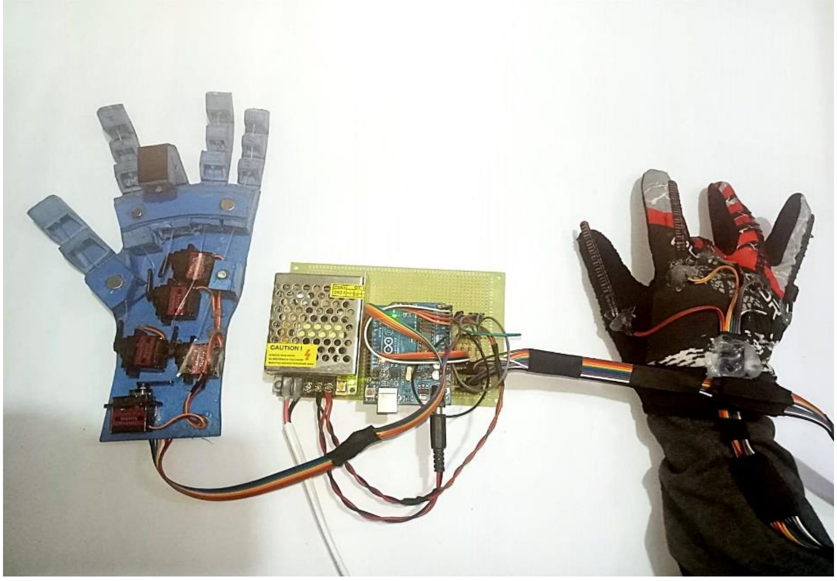

Fig 4.1.3: Middle finger activation

Fourth finger activation (Ring Finger):

Just like any other finger, the flex sensor of the fourth one detects a bend. The Arduino moves its corresponding servo motor. It is typically the ring finger that moves while others remain in position. The issues here may be because of response delay which may arise as a result of cumulative processing load especially when controlling many fingers at once.

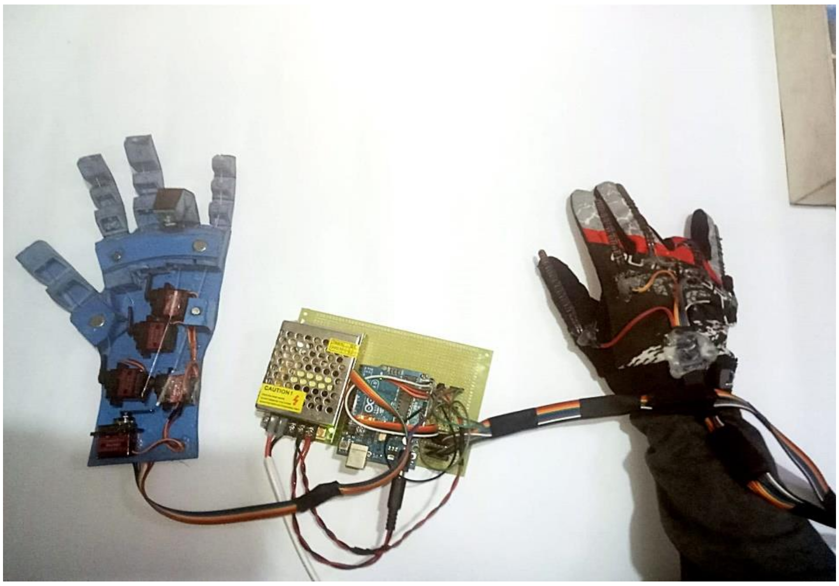

Fig 4.1.4: Ring finger activation

Fifth finger activation (Pinky Finger):

Data from pinky finger's flex sensor are sent to Arduino which adjusts the servo motor to mimic pinky finger flexion. This is usually a delicate movement, and it must be ensured that there is no impact on the general stability of this hand with respect to moving this finger correctly. A problem can occur here due to less torque required by motors because of smaller size and range of motions for little fingers.

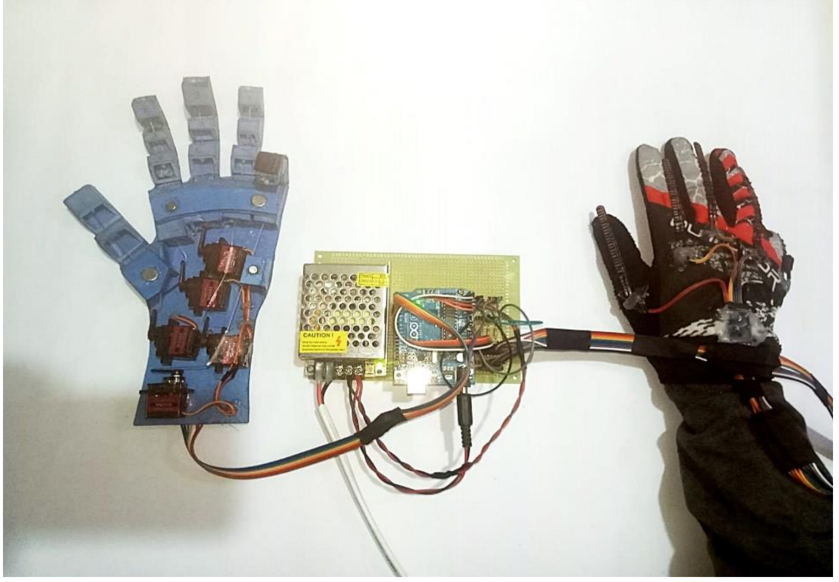

Fig 4.1.5: Thumb finger activation

When all fingers are activated at once:

When all the flex sensors detect bending at the same time, Arduino processes each input from each sensor in parallel. Each of the finger's flexing angles is adjusted by their own respective servo motor. This means that depending on what orientation the servo motors are set to, the hand can either be used in a fist or it can be used to grip something. The main problem here is coordinating and controlling all servos so that they move smoothly together. Additionally, as all servos will need to work simultaneously, there should be an adequate power supply that can cope with increased current demand.

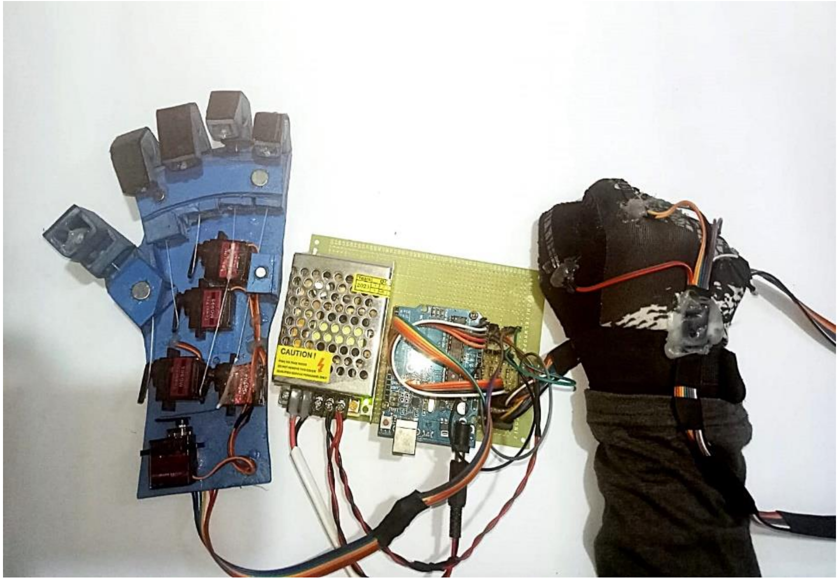

Fig 4.1.6: All finger activation

4.2 Discussions

This robotic hand project has successfully combined flex sensors, servo motors, and an Arduino Uno for simulating human hand movements. Gestures can be formed as a result of the ability to move individual fingers. Nonetheless, some challenges were brought up such as sensitivity of sensors; servo motor torque and many motors control synchronized among other things like this. Such issues if tackled could bring about better efficiency and precision from the robot arm.

This research lays down a strong foundation for more advanced robotic hands that might incorporate feedback mechanisms, better sensors and stronger actuators for accomplishing hard tasks by robots. In conclusion, this project shows that it is possible to create low-cost robotic prosthetics or assistive devices composed of off-the-shelf components adaptable for various applications including medical rehabilitation, teleoperation or even human computer interaction. The incident demonstrated the importance of comprehensive planning, elaborate documentation and meticulous execution in every stage of the project. It also underscored the necessity for extensive testing and validation to identify potential pitfalls and fix them early on during development. This project also reminded us how crucial it is to double check connections and soldering in order to prevent any damage due to soldering mistakes since wrong connections and soldering made five flex sensors useless at first thereby necessitating their replacement.

CHAPTER 5
PROJECT MANAGEMENT

5.1 Task, Schedule and Milestones

Task Schedule

- **Week 1-2**: Initial Planning and Component Acquisition
  - ✓ Set goals for the project and defined the project specifications.
  - ✓ Got all the things needed (Arduino UNO, flex sensors, servo motors, wires, and power supply)
- **Week 3-4**: Hardware Setup and Initial Assembly
  - ✓ Attached the flex sensors on a glove.
  - ✓ Wired up the flex sensors to the Arduino analog pins.
  - ✓ Fixed servos on the robotic hand and interfaced them to Arduino digital pins
- **Week 5-6**: Coding and Initial Testing
  - ✓ Created an Arduino program code which could read sensor values as well as control servos.
  - ✓ Did initial tests in order to satisfy basic requirements of our design.
- **Week 7**: Calibration and Fine-Tuning
  - ✓ Calibrated flex sensors for more precise reading accuracy.
  - ✓ Fine-tuned servo angles as well as codes' thresholds for accurate finger movements
- **Week 8-10**: Full System Integration and Testing
  - ✓ Integrated all components into one working system.
  - ✓ Conducted comprehensive test to ensure appropriate operation and response rate with minimal delays or time lags in a bidirectional movement system like this one when using two FSRs per finger.
- **Week 11-12**: Final Adjustments and Documentation
  - ✓ Made final adjustments based on testing results after calibration of threshold voltages for each individual channel.
  - ✓ Documented the project, which includes design specifications, analysis and reflection on lessons learnt.

Milestones

- ✓ Component Procurement Finished at the end of week 2.
- ✓ Initial Construction Done at the end of week 4.
- ✓ Code Development and Deployment Done at the end of week 6.
- ✓ Calibration Done at the end of week 7.
- ✓ Full System Test Completed at the End of Week 10.
- ✓ Find The Cost of the Resources

5.2 Resources and Cost Management

The Cost of the Resources

Name	No. of Uses	Amounts (Tk)
Arduino Uno	01	1050
Flex Sensors	05	6000
Servo Motors	05	1250
Wiring and Connectors	As required	500
Power Supply	01	700
Glove	01	300
Vero board	01	100
Craft Board	01	250
Total cost		**10,150**

Table 5.2: Cost of the Resources

Cost Management

- ✓ Set a predetermined amount for each resource and selected the ones that were acceptable and high quality.
- ✓ Kept track of the total cost to maintain the budget.
- ✓ Preferably bought equipment that was sold in large quantities so as to cut costs.

5.3 Lesson Learned

Component Compatibility

- ✓ There was an assurance of the compatibility of all components with Arduino Uno so that no integration challenges will be there.
- ✓ We appreciated the vitality of verifying voltage and current ratings to evade component damage.

Sensor Calibration

- ✓ We realized that thorough calibration was necessary to get accurate sensor readings.
- ✓ It came to my knowledge that different flex sensors may differ in sensitivity necessitating individual calibration.

Power Management

- ✓ We acknowledged the necessity of a reliable power supply capable of dealing with current needs from numerous servos.
- ✓ On this note, I maintained stable power distribution against voltage drops and erratic behavior.

Iterative Testing and Adjustment

- ✓ The emphasis on iterative testing and adjustment to fine-tune the system was very strong.
- ✓ Small changes in code as well as hardware tuning could make a big difference in performance realized during my study

Documentation and Planning

- ✓ Awareness has been made about why detailed documentation at each step is essential for any project undertaken.
- ✓ At the same time, we have come to realize that through planning together timing this would help us to complete our projects on time, while managing our resources properly

Connection and Soldering Issues

- ✓ Faced issues with wrong connections and soldering problems, which led to the damage of all 5 flex sensors.
- ✓ Had to repurchase the flex sensors, reinforcing the importance of careful and accurate soldering and wiring to avoid costly mistakes.

CHAPTER 6
IMPACT ASSESSMENT OF THE PROJECT

6.1 Economical, Societal and Global Impact

Use of flex sensors in robotic hands has diverse implications to different areas such as economic, societal and global spheres.

Economic Impact

- **Employment Generation**: The progress of robotic hands leads to opening up new job markets in such areas as robotics engineering, manufacturing, maintenance and programming. Moreover, it broadens employment opportunities within the medical and assistive technology sectors where these devices are commonly used.
- **GDP Contribution**: Such a scenario improves productivity and efficiency in various fields like healthcare and manufacturing thus contributing to economic growth. This leads to the manufacture of products of high quality hence promoting economic development.
- **Cost Effectiveness**: Robotic hands can undertake repetitive tasks with accuracy levels that result into reduction of labor costs while increasing operational efficiency. Of this reason, there is decrease in production costs thus leading to decreased consumer prices as well.

Impacts on Society

- **Life Enhancing**: The quality-of-life improvement is an extraordinary benefit of robotic arms that can enable a disabled person to prepare meals independently. This includes everyone and actively involves them in the community.
- **Medical Improvements**: Medical robotics with flex sensors are used for surgeries and rehabilitation, which quickens patients' recovery periods resulting in better outcomes.
- **Teaching and Research**: Employing robot hands in educational institutions instils interest for sciences (Science, Technology, Engineering, Mathematics), producing new inventors and scientists.

Impacts on the World

- **Technological Leadership**: States investing in advanced robotics can attract global technology market supremacy, foreign alliances and capital.
- **Global Collaboration**: Creation of robot hands enables worldwide research interaction between scientists of different nations, thus creating a body of knowledge that is accessible to all.

Infrastructure Development and Energy Consumption

- **Infrastructure**: The introduction of robot hands into manufacturing and other industries will require upgrading existing infrastructures. These include adoption of new robotic workstations as well as transforming production lines.
- **Energy Usage and Generation**: High-tech robots are more energy-efficient than human labor which saves energy on optimal actions performance. However, significant energy resources may be necessary during initiation stages when developing and deploying them**.**

6.2 Environmental and Ethical Issues

Environmental Problems

- **Sustainable Use of Resources**: In the production and deployment of robotic hands, sustainable techniques should be applied like using eco-friendly components and minimizing waste. Environmental impact can be mitigated by doing life cycle assessments.
- **Environmental Aesthetics**: The robot's hands should be integrated in various surroundings so as to make them beautiful and avert visual pollution such that they can merge with the environment already existing.

Ethical Issues

- **Privacy of Data:** In numerous occasions, robotic hands collect data for processing so that they could function effectively. This information has to be handled ethically and securely in respect for users' privacy.
- **Responsibility and Accountability:** Healthcare industry and other sectors like manufacturing need some guidelines to define who should be responsible for the action of robots and account on their behavior.

- **Accessibility and Equity:** It is important to make sure that all people irrespective of their socio-economic status have an equal opportunity to access the innovations of the robot hand.

6.3 Utilization of Existing Standards or Codes

Other Relevant Standards as well as Safety Issues

- **ISO standards:** In terms of safety and quality, it is necessary to comply with ISO which sets international benchmarks for robotics and automation.
- **Safety Regulations:** Develop a holistic security framework by ensuring risks are minimized in human-machine collaboration setups.
- **Compliance with Laws**: Ensuring that healthcare, data protection, privacy laws local, national and international are fully complied in relation to robot hands used.

6.4 Other Concerns

Probable Issues

- **Technical Challenges:** For instance, these technical challenges include better sensor accuracy, longer life span and lower cost.
- **Public Perception:** It is how the public thinks about robots that matter when it comes to trusting them. Convincing them of their merits backed by sound communication channels alongside robust safety precautions can eliminate resistance.
- **Long-Term Viability:** The flexibility of Robotic Hands towards future technologies as well as societal transformations makes them viable in the long run.

CHAPTER 7
CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

This project was about making a robotic hand which would be capable of imitating human gestures quite accurately through the use of flex sensors able to detect the bending or opening of fingers. We achieved all our objectives as we were able to quantify finger bending using flex sensors and hence, accurately reproduce postures of Robotic Hand. According to the stakeholder's functional specifications, this system worked efficiently and responsively. In addition, other crucial achievements include:

- **Smooth Integration:** Live translation of human finger actions by including continuous movement screening in the robot hand.
- **Precision plus Quickness:** Operating with very minimal latencies, this system demonstrated high accuracy in detecting and mimicking movements by fingers.
- **User-Friendly Interface:** A user-friendly framework was created for managing and calibrating robotic hand.

For example, this method applies well in prosthetics since it improves their capability for making more intricate movements that are beyond dialing phones numbers. Moreover, it is relevant for teleoperation systems used in hazardous environments as well as rehabilitation devices aiding patients in restoration of manual functions.

7.2 New Skills and Experiences Learned

During the course of the project, various new abilities and exposures were gained. Some of these include:

- **Sensor Integration**: Practical experience was acquired in integrating flex sensors with microcontrollers and analyzing sensor information.
- **Programming and Control Systems**: This also improved the ability to write microcontroller programs using Python, C++, and control algorithms that respond in real time.
- **Hardware Prototyping**: Concepts about hardware prototyping such as troubleshooting electrical, mechanical parts, 3D printing and assembling were learnt.

- **Signal Processing**: Additional insight on signal processing techniques for filtering and calibration of sensor data to ensure accurate interpretation was realized.
- **Interdisciplinary Collaboration**: In general, working across disciplines is a valuable asset especially when one has knowledge in electronics, mechanics and computer science which are put together to form one system.

7.3 Future Recommendations

The following recommendations may be considered a solution to this problem:

- **For Higher Sensor Precision**: It can be done by making use of advanced or alternative types of sensors like capacitive or optical sensors that could improve the precision and detection range of motion.
- **Control Algorithms That Are Much Better**: A more effective control algorithm for different hand sizes and grip strength will make natural and flexible hand movements possible.
- **Wireless Capability**: By integrating wireless communication modules, remote control would become possible thereby doing away with limitations imposed by physical connections.
- **Strength and Durability**: The emphasis must be on enhancing the system’s robustness in order to make it tough enough to withstand real-world situations, hence wear out less under realistic circumstances.
- **Machine Learning Integration**: To increase the adaptability and efficiency of the system, machine learning techniques should be employed to anticipate and optimize hand motions based on user behavior.
- **GUI Enhancement**: Further refine the User Interface (UI) so as to make calibration simple while also facilitating easy manipulation even for non-technical users
- **Expansion into Virtual Reality (VR) / Augmented Reality (AR)**: In other words, the robot’s hand as far as virtual reality or augmented reality is concerned could allow people using it to have a fuller experience.

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APPENDIX A

TURNITIN REPORT

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APPENDIX B

COMPLEX ENGINEERING PROBLEM SOLVING AND ENGINEERING ACTIVITIES

Complex Engineering Problems (P) Solving		
	Attributes	Statement from students
P1	Depth of knowledge required	The project needs a good understanding of **electrical engineering** so that the various electrical components are handled well. Programming microcontroller and implementing control algorithms calls for knowledge in **coding**. It is important to know **signal processing** to ensure accuracy of sensor data interpretation. To efficiently distribute and guarantee reliable power across the system, one must have **power management skills.**
P2	Depth of analysis required	**Sensor Calibration** involves is rectifying sensors so that we can be able to give accurate measurements without fail. **Signal Filtering** is necessary to facilitate removal of noise from data as well as enhancing quality of signals produced by the system. Optimization through **Power Distribution** analysis ensures efficient delivery of power to different parts of a system. A meticulous scrutiny all over the set up called **System Testing** for detection and correction of any flaws that may be present.

P3	Interdependence	For the **flex sensors**, we rely on **Arduino Uno** to get information which will assist in controlling movements made by robot hand or fingers. In order to carry out this translation from sensor data into precise mechanical actions, an Arduino uno interfaces with **servo motors**. The rest should also be carefully managed even if it includes other **components** like sensors and actuators found in the machine.

Complex Engineering Problems (P) Solving		
	Attributes	Statement from students
A1	Range of resources	We employ numerous resources like Arduino Uno for microcontroller projects, flex sensors to sense motion and pressure, servo motors for precise actuation, plus wires and connectors aiding in the assembly of their systems in an efficient manner.
A2	Innovation	We also experiment with new ideas such as; inexpensive prosthetics that increase their availability, adaptive controllers that improve response rates and reactive robotics facilitating interaction or advanced human-machine interfaces improving better technology integration with user needs.
A3	Consequences of society and environment	The objective of these projects is to make assistive devices accessible through technological innovations; improving technology towards higher resource efficiency levels; designing products which are capable of sustaining the environment.

}

APPENDIX C
PROGRAM CODE

```
#include <Servo.h>

const int flexPins[5] = {A0, A1, A2, A3, A4}; // Flex sensor analog pins

const int servoPins[5] = {3, 4, 5, 6, 7}; // Servo motor control pins

Servo servos[5];

const int thresholds[5][3] = {

{50, 100, 150}, // Adjust according to your sensor's behavior

{50, 100, 150},

{50, 100, 150},

{50, 100, 150},

{50, 100, 150}

};


void setup() {

Serial.begin(9600); // Start serial communication


// Attach servos to their pins

for (int i = 0; i < 5; i++) {

servos[i].attach(servoPins[i]);

}

}


void loop() {
```

```
for (int i = 0; i < 5; i++) {
int flexValue = analogRead(flexPins[i]);
int angle = 0; // Initialize servo angle
if (flexValue < thresholds[i][0]) {
angle = 0; // Below first threshold, servo angle is 0 degrees
} else if (flexValue < thresholds[i][1]) {
angle = 10; // Between first and second threshold, servo angle is 10 degrees
} else if (flexValue < thresholds[i][2]) {
angle = 20; // Between second and third threshold, servo angle is 20 degrees
} else {
angle = 180; // Above third threshold, servo angle is 180 degrees
}
servos[i].write(angle);
Serial.print("Flex Sensor ");
Serial.print(i);
Serial.print(" Value: ");
Serial.print(flexValue);
Serial.print(", Servo ");
Serial.print(i);
Serial.print(" Angle: ");
Serial.println(angle);
}
delay(100);
}
```