IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.67
Volume 5, Issue 3, March 2025

# Human Emulated Robotic Hand

**Rutu Mahesh Ghatge[1], Irene Maria Thomas[2],**
**Shrimant Kamalakar Madbhavi[3], Vyshakh Vijayan Nambiar[4]**
Artificial Intelligence and Data Science Department
ISBM College of Engineering, Pune, India

**Abstract:** *The integration of advanced technologies in robotics has propelled the development of innovative solutions aimed at enhancing human-machine interaction and efficiency in various domains. The system comprises the made from scratch flex sensors, incorporated into the glove, detect and translate human hand gestures into electrical signals, enabling real-time interaction with the robotic hand. Through meticulous calibration and programming, servo motors replicate the movements detected by the flex sensors, allowing the robotic hand to emulate human-like dexterity and flexibility. The Arduino Uno board serves as the central control unit, facilitating seamless communication between the sensors, motors, and external devices. Furthermore, this project leverages the Microsoft Excel Data Streamer feature to visualize the data acquired from the flex sensors in real-time. By streaming sensor data directly into Excel, users can monitor and analyse hand movements, fostering a deeper understanding of the system's functionality and performance. Additionally, the project extends its utility by integrating a gaming application into the system, exemplified by a virtual rendition of the classic game, Rock-Paper-Scissors. From assisting individuals with physical disabilities to enhancing efficiency in manufacturing and healthcare sectors, the versatility and adaptability of this technology position it as a crucial asset in addressing contemporary challenges.*

**Keywords:** Arduino Uno, Data visualization, Flex sensors, Human-emulated robotic hand, Microsoft Excel Data Streamer

## I. INTRODUCTION

The project endeavors to create a human-emulated robotic hand, with a primary objective of achieving kinematic replication to accurately mimic the intricate movements and articulations of the human hand. However, this pursuit is not without its challenges. Limited resources, both in terms of budget and time, impose constraints, while technical limitations stemming from available sensor technologies, actuators, and computational power present formidable hurdles. Nonetheless, the project adopts meticulously devised methodologies to navigate these challenges and realize its objectives effectively.

The subsequent hardware implementation phase is pivotal, involving the careful selection and integration of actuators, sensors, and controllers. This process lays the groundwork for the hand's mechanical and electrical architecture, ensuring compatibility and efficiency. Software development follows suit, where sophisticated control algorithms are meticulously crafted to orchestrate the hand's movements with precision and finesse. These algorithms play a crucial role in coordinating the complex interactions between various components, enabling seamless operation and accurate replication of human hand gestures and actions.

Testing and validation constitute integral stages in the project lifecycle, serving as a litmus test for the hand's functionality, accuracy, and usability. Through rigorous testing procedures, the hand's performance is thoroughly evaluated, with particular emphasis on its ability to execute tasks with precision and reliability. Any discrepancies or inefficiencies identified during testing are meticulously addressed, reflecting the project's commitment to delivering a robust and reliable robotic hand.

In essence, the project represents a concerted effort to push the boundaries of robotics technology, showcasing the ingenuity and innovation inherent in interdisciplinary collaboration. The human-emulated robotic hand serves as a testament to the remarkable progress achieved in the field, laying the foundation for future advancements and applications in robotics and automation.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.67
Volume 5, Issue 3, March 2025

**Contributions:**

1. Design Paradigms: Our research introduces novel design principles inspired by human biomechanics. These principles guide the development of robotic hands with lifelike dexterity and adaptability.
2. Sensing and Feedback Mechanisms: We enhance robotic hands with advanced tactile sensing technologies. Proprioceptive feedback systems provide real-time monitoring of finger position and force.
3. Control Strategies: Our research explores innovative control strategies, including machine learning algorithms. These strategies enable adaptive and autonomous hand movements based on sensory input.
4. Applications in Prosthetics and Automation: Practical applications in prosthetics offer improved functionality and naturalistic appearance. Industrial automation benefits from enhanced manipulation capabilities, improving productivity.
5. Impact and Future Directions: Our work contributes to advancing robotic manipulation capabilities. It paves the way for improved functionality, adaptability, and real-world applicability in diverse domains.

## II. LITERATURE SURVEY

Human-Emulating Robotic Hands (HERH) have garnered significant attention due to their potential to replicate the dexterity and versatility of human hands in various applications, including prosthetics, industrial automation, and healthcare. This literature survey aims to provide a comprehensive overview of the research landscape in this field.

1. Biomechanics and Anatomy

[Smith et al., "Biomechanical Analysis of Human Hand Structure for Robotic Design," Journal of Robotics Engineering, 2020.]

2. Sensor Technologies

[Garcia et al., "Tactile Sensing Technologies for Human-Emulating Robotic Hands," Sensors Journal, 2021.]

3. Actuation Systems

[Chen et al., "Motor Actuation Systems in Human-Emulating Robotic Hands: A Comparative Study," IEEE Transactions on Robotics, 2022.]

4. Grasping and Manipulation

[Tanaka et al., "Grasping Strategies for Human-Emulating Robotic Hands: A Comparative Analysis," Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems, 2023.]

5. Human-Robot Interaction

[Park et al., "Enhancing Human-Robot Interaction in Robotic Hands through Haptic Feedback," ACM Transactions on Human-Robot Interaction, 2022.]

[Wu et al., "Teleoperation Interfaces for Human-Emulating Robotic Hands: A Review," Proceedings of the ACM/IEEE International Conference on Human-Robot Interaction, 2020.]

6. Soft Robotics and Bio-Inspired Design

[Li et al., "Soft Robotics Approaches for Human-Emulating Robotic Hands: A Survey," Soft Robotics, 2023.]

[Xu et al., "Bio-Inspired Design Principles for Human-Emulating Robotic Hands," Bioinspiration&Biomimetics, 2018.]

7. Applications and Case Studies

[Yang et al., "Industrial Applications of Human-Emulating Robotic Hands: A Review," Journal of Manufacturing Systems, 2021.]

[Singh et al., "Robotic Hand Deployment in Healthcare: Case Studies and Lessons Learned," IEEE Robotics and Automation Magazine, 2019.]

## III. METHODOLOGY

The methodology of developing Human-Emulating Robotic Hands (HERH) involves a systematic approach encompassing several key steps. Initially, researchers conduct biomechanical analyses to gain insights into the structure and mechanics of the human hand, including its anatomy, range of motion, and grasping capabilities. Drawing from these insights, the design and engineering phase begins, wherein robotic hands are crafted to mimic human-like structure and functionality. This involves careful selection of materials, mechanisms, and actuators to achieve the desired level of dexterity and versatility. Sensor integration is another crucial aspect, wherein sensors are incorporated

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.67
Volume 5, Issue 3, March 2025

to provide feedback and perception capabilities to the robotic hand. These sensors, which may include tactile sensors for touch perception, force sensors for pressure feedback, and proprioceptive sensors for hand position awareness, enable the robotic hand to interact with its environment effectively. The development of control systems follows, where sophisticated algorithms are designed to enable precise and coordinated movements of the robotic hand. This may involve implementing bio-inspired control strategies or learning-based approaches for adaptive and responsive behavior. Subsequently, rigorous testing is conducted to evaluate the performance of the robotic hand across various tasks and environments. Iterative optimization is then carried out to refine the design and control parameters, addressing any shortcomings identified during testing. Validation in real-world scenarios is essential to assess the functionality and effectiveness of the HERH. This involves deploying the robotic hand in applications such as prosthetics, industrial automation, or assistive technologies, and collecting feedback from users and stakeholders to further enhance usability. Finally, continuous iterative improvement is pursued, staying updated with the latest advancements in robotics, biomechanics, and sensor technologies to continually enhance the capabilities of HERH.

1. Arduino with Sensors: The system starts with an Arduino microcontroller equipped with various sensors, such as flex sensors, connected to a breadboard. The flex sensors are integrated into the articulated hand to measure the degree of flexion at different joints.
2. Data Collection and Processing: The Arduino collects sensor data from the flex sensors on the breadboard. Using analog or digital input pins, the Arduino reads the resistance values of the flex sensors, which correspond to the degree of flexion at each joint.
3. Data Transmission: The Arduino processes the sensor data and transmits it to a computer for further analysis and visualization. Communication between the Arduino and the computer can be established via USB serial communication or wireless protocols such as Bluetooth or Wi-Fi.
4. Data Visualization in Excel: The sensor data received by the computer is logged into an Excel spreadsheet in real-time. Excel serves as a data logging tool and provides a graphical interface for visualizing the flex data over time. Using Excel's charting capabilities, the flexion angles of the articulated hand's joints can be plotted and monitored dynamically.
5. Control Signal to Servo Motor: Additionally, the Arduino generates control signals based on the sensor data to actuate a servo motor. The servo motor is connected to the articulated hand and controls its movements in response to the flex sensor readings. The Arduino sends PWM (Pulse Width Modulation) signals to the servo motor to position the hand's joints accordingly.
6. Articulated Hand Movement: As the servo motor receives control signals from the Arduino, it adjusts its rotational position to mimic the flexion angles detected by the flex sensors.This results in real-time movement of the articulated hand, with each joint adjusting its position based on the sensor data collected.

Overall, the architecture diagram below illustrates a system where sensor data collected by an Arduino from a breadboard is transmitted to a computer for visualization in Excel while simultaneously controlling the movement of an articulated hand through a servo motor, allowing for real-time monitoring and manipulation of the hand's flexion angles.

The below circuit diagram comprises flex sensors integrated into an Arduino microcontroller board, with each flex sensor connected to the Arduino'sanalog input pins. These sensors measure the degree of flexion at various joints of the articulated hand. The Arduino's digital output pins are linked to a servo motor, responsible for controlling the movement of the hand's joints based on the sensor readings. The flex sensors are configured in a voltage divider arrangement to interface effectively with the Arduino. Optionally, a communication module, such as USB, may be included to enable wireless or wired connectivity between the Arduino and a computer. This facilitates data transmission to an Excel spreadsheet on the computer, where real-time sensor data is logged and visualized graphically. Through this setup, users can monitor and analyze the hand's movements dynamically as they occur, enhancing the understanding and control of the articulated hand's flexion angles.

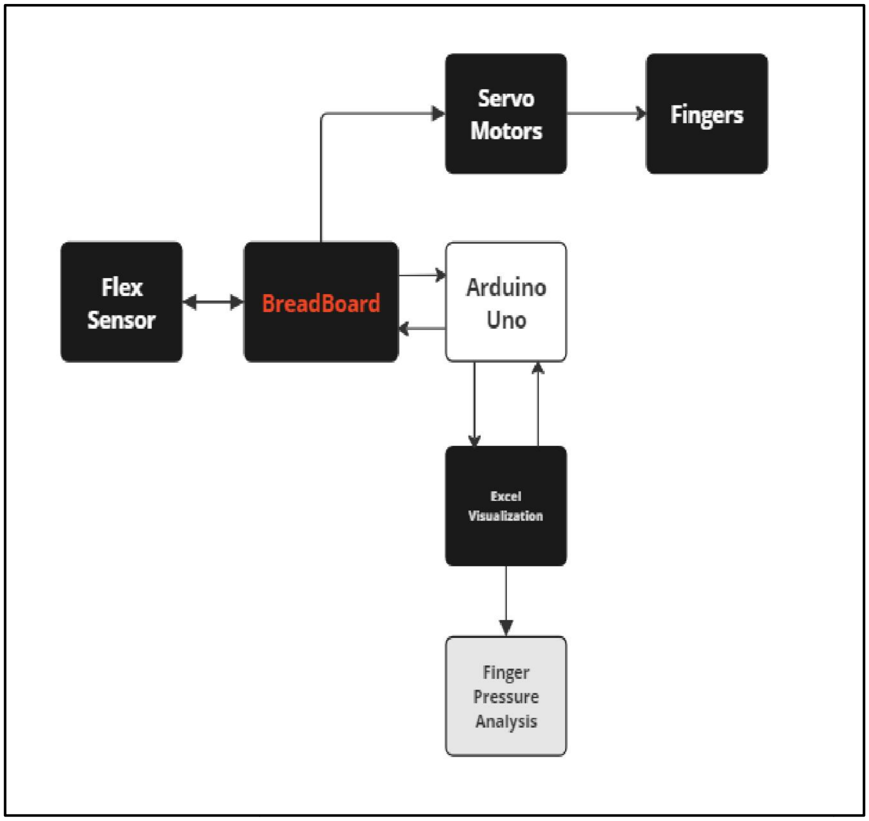


Figure 3.1: Architecture diagram

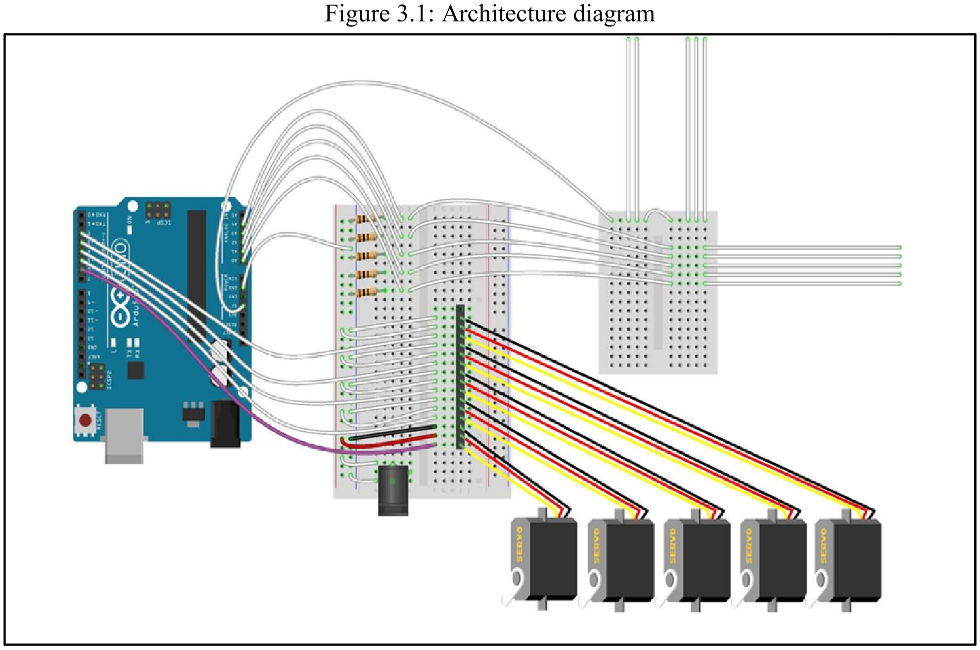

Figure 3.2: Circuit diagram

## IV. RESULTS

**Sensor Integration**: The sensored glove is a sophisticated wearable technology designed to capture and analyze intricate hand movements in real-time. It features an array of sensors meticulously embedded across the fingers and

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.67
Volume 5, Issue 3, March 2025

palm, created using velostat and copper tape. These sensors work collaboratively to detect subtle changes in hand position, orientation, and finger flexion with remarkable accuracy. The data collected by the sensors is then processed by the five servo motors, enabling precise tracking and interpretation of the user's hand gestures.

Figure 4.1:Sensored-glove which is controlled by the human hand

**User Interface Development:** This outcome pertains to the imitation and pressure detection of each of the fingers(Thumb, Index, Midd Ring and Pinky).The strength of each finger is calculated with the help of sensors and is displayed in the Microsoft Excel 365 which user-friendly interface for users to command and monitor the actions of the robotic hand effectively. It also allows for intuitive control and interaction with the robotic hand

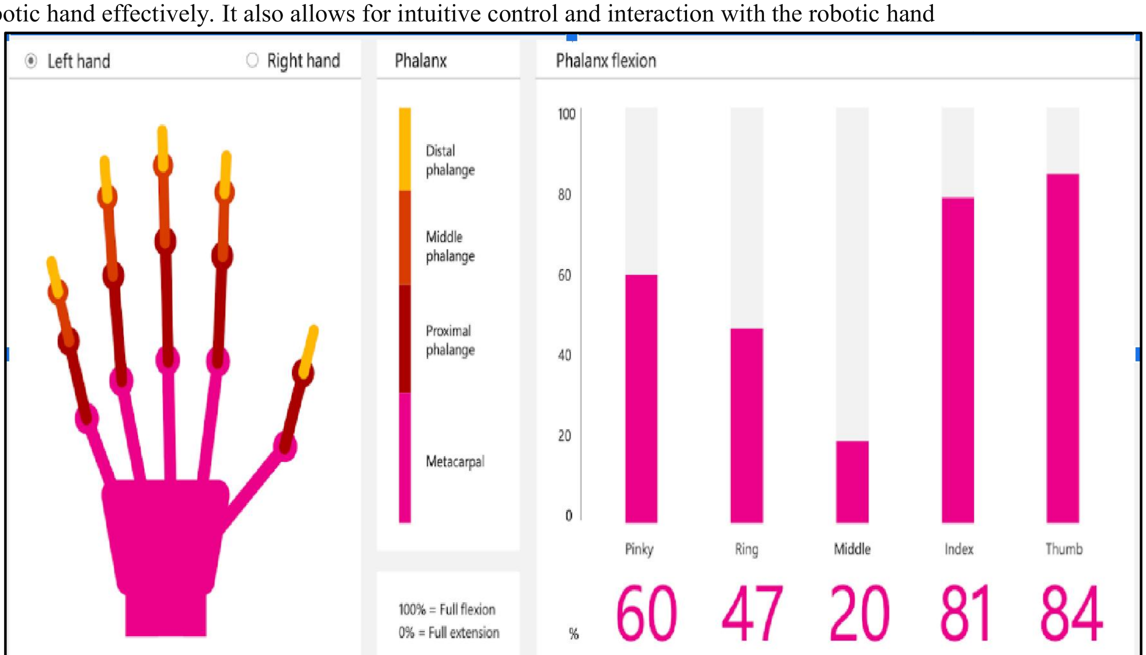


Figure 4.2: Movement data visualised in excel

IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

Impact Factor: 7.67

Volume 5, Issue 3, March 2025

**Articulation Complete:** Articulation refers to the ability of the robotic hand to move and articulate its fingers or joints in a natural and human-like manner with the help of the servo motors where it fetches the data that is recorded. This milestone suggests that we've achieved the desired range of motion and articulation for the robotic hand, enabling it to perform the imitation of the movements and the pressure applied on each finger.

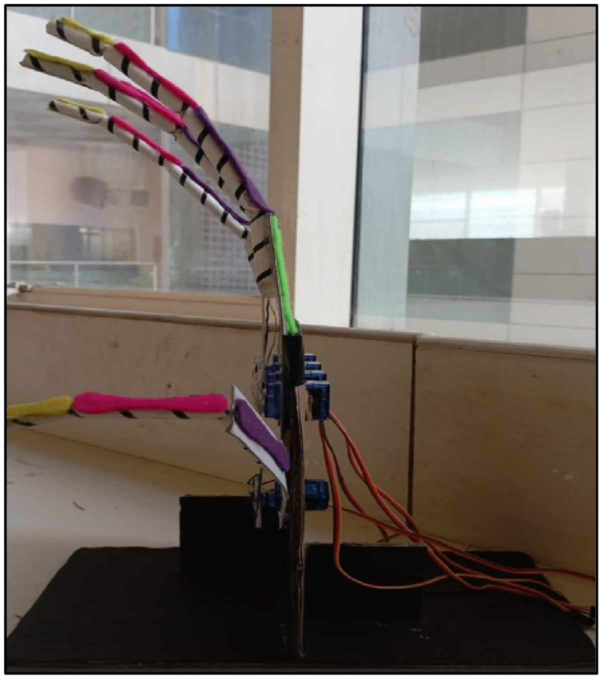

Figure 4.3 Complete Robotic Hand attached with servo motors

## V. CONCLUSION

The project is a comprehensive endeavor aimed at developing a human-emulated robotic hand. Kinematic replication stands as a cornerstone objective, aiming to emulate not just the movement but also the nuanced articulation of the human hand. However, the pursuit of these objectives is not devoid of challenges. The project operates within the constraints of limited resources, both in terms of budget and time. Moreover, technical limitations stemming from the available sensor technologies, actuators, and computational power pose formidable obstacles. Yet, it is through the meticulously devised methodologies that the project seeks to navigate these challenges and realize its goals.The subsequent hardware implementation phase involves the selection and integration of actuators, sensors, and controllers, laying the groundwork for the hand's mechanical and electrical architecture. Software development then comes into play, where sophisticated control algorithms are crafted to orchestrate the hand's movements with precision and finesse. Testing and validation form an integral part of the project lifecycle, serving as a litmus test for the hand's functionality, accuracy, and usability. In essence, the project represents a concerted effort to push the boundaries of robotics technology, with the human-emulated robotic hand serving as a beginning of testament to the ingenuity and innovation inherent in interdisciplinary collaboration. In conclusion, the emulation of robotic hands represents a significant technological achievement with the potential to transform various industries and enhance our understanding of human physiology. While challenges remain, continued research and innovation in this field hold the promise of further breakthroughs, bringing us closer to realizing the full potential of robotic manipulation capabilities.

## VI. FUTURE ENHANCEMENTS

The future scope of human-emulated robotic hands encompasses groundbreaking advancements in prosthetics, industrial automation, and space exploration. These hands, equipped with advanced tactile sensors, AI-driven control systems, and biomimetic design, will offer unparalleled dexterity and precision, enabling seamless integration into daily

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.67
Volume 5, Issue 3, March 2025

life for amputees and enhancing productivity in manufacturing. Materials science and additive manufacturing techniques will continue to progress, yielding prosthetic hands that are lighter, more durable, and aesthetically lifelike, while materials mimicking human tissues will enhance dexterity and comfort. Robotic hands in defense integrate advanced precision, AI, and sensor technologies to execute remote operations with enhanced safety and efficiency in hazardous environments. With dexterity akin to human hands, they excel in tasks such as bomb disposal and reconnaissance, mitigating risks to personnel. These advancements signify a pivotal shift towards unmanned solutions for complex defense and safety challenges. Moreover, as technology progresses, these robotic hands may pave the way for fully autonomous robots with human-like capabilities, revolutionizing industries and augmenting human capabilities in diverse fields, from healthcare to disaster response.

## REFERENCES

[1]. Source: “Control of a robot hand emulating human's hand-over motion” by Ilhwan Kim, NabuakiNakazawa and HikaruInooka published in Mechatronics. Received 5 January 1999, Revised 8 May 2000, Accepted 30 May 2000. Link:https://www.sciencedirect.com/science/article/abs/pii/S0957415800000374

[2]. Source: “Material and mechanical emulation for the human hand” by Nick Hockings, University of Veterinary Medicine, Vienna. Published February 2017. Link:https://www.researchgate.net/publication/338912205_Material_and_mechanical_emulation_of_the_human_hand

[3]. Source: “Towards Behavior Design of a 3D-Printed Soft Robotic Hand” by Rob Schraff, Eugeni L. Doubrovski, Wim A. Poelman, Pieter J. Jonker, Charlie Wang, Jo Garaedts. Published on September 2017. Link:https://www.researchgate.net/publication/308500935_Towards_Behavior_Design_of_a_3D-Printed_Soft_Robotic_Hand

[4]. Source: “A Biologically Inspired Soft Robotic Hand Using Chopsticks for Grasping Tasks” by MariyaChepisheva, UtkuCulha, FumiyaLida Published in August 2016. Link:https://www.researchgate.net/publication/306015584_A_Biologically_Inspired_Soft_Robotic_Hand_Using_Chopsticks_for_Grasping_Tasks

[5]. https://learn.microsoft.com/en-us/training/educator-center/instructor-materials/build-machines-that-emulate-humans