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BIONIC HAND V1(SUNBOARD)

A 16 YEAR OLD MADE VISION SENSOR BONIC HAND FROM SCRATCH

YOUTUBE :@DHRUVTHATSME2009

Introduction

At 16, I developed **'Bionic Hand Version 1'** using Arduino UNO ,Laptop Camera and Sunboard(foamboard) to prove that advanced robotics can be accessible and affordable. I designed this prototype to operate via computer vision using a laptop camera (vision sensor), translating real-time movements into mechanical action. To keep the project budget-friendly and accessible to those without high-end equipment, I bypassed 3D printing entirely, hand-building the entire structure from sunboard (foamboard). By optimizing my materials and code, I successfully completed my first robotics project with a total build cost of under **₹2,500 ($28 USD)**.NOTE : The cost of materials depends place to place.And I know this isn't perfect project but I will Improve in future versions.

Project Overview

The Vision-Controlled System Unlike traditional robotic hands that rely on physical controllers or bulky sensors, my project utilizes a **laptop-integrated vision sensor**. By using a camera to track my own hand movements in real-time, the bionic hand acts as a mirror, translating my gestures into mechanical motion without any physical tether between the user and the device.

Innovation Through Resourcefulness A key highlight of this project is the construction method. To ensure the design remains accessible to those without a 3D printer, I handcrafted the entire chassis using **sunboard (foamboard)**. This material provided the perfect balance of being lightweight for the motors and easy to modify during the prototyping phase.

Economic Impact By prioritizing smart material choices—such as utilizing **MG90S metal-gear servos** for their durability and affordability—I successfully kept the total build cost under **₹2,500 (approx. $28 USD)**. This makes **Bionic Hand Version 1** a viable proof-of-concept for low-cost, vision-based prosthetic alternatives.

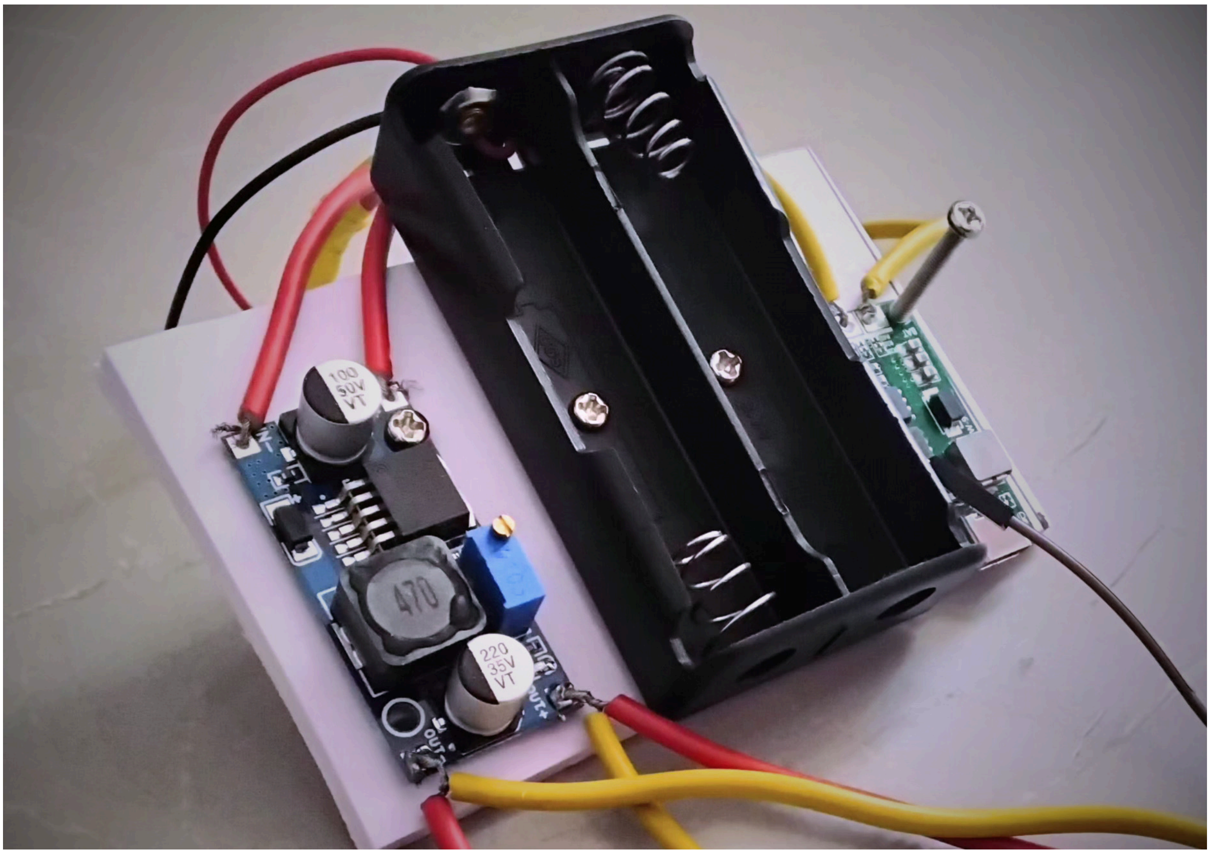
Design and Development: Mechanical & Electronic Integration

Mechanical Architecture: Tendon-Driven System The finger assembly utilizes a custom **tendon-driven mechanism** designed for maximum flexibility without the need for traditional hinges.

- **Trapezoidal Geometry:** Each finger segment is precisely carved into a trapezium shape. This allows the segments to sit flush when extended and creates a natural "stop" and folding angle when the tendon is pulled, mimicking human finger joints.
- **Dual-Channel Tendon Routing:** I engineered a "loop-through" system where a high-tension **fishing line** passes through two dedicated holes in every segment. This ensures centered pulling force and prevents the segments from twisting during contraction.
- **Passive Tension Return:** To allow the hand to reset, I integrated **recoil rubber segments** on the back of the fingers. These provide the necessary counter-tension to pull the segments back into an open position once the servo releases the line.
- **Custom Sunboard Pulleys:** To translate the circular motion of the **MG90S servos** into linear pull, I manufactured custom pulleys from sunboard. This ensures the fishing line remains secure and moves with consistent mechanical advantage.

Electronic Control & Software Stack The project bridges the gap between highlevel computer vision and low-level hardware control through a dual-language architecture.

- **Vision Processing (Python):** Using **OpenCV** and **MediaPipe**, I developed a script that tracks 21 hand landmarks in real-time. The software calculates the distance between finger tips and the palm to determine the "Open/Closed" state.
- **Firmware (Arduino IDE):** I programmed an **Arduino UNO** to act as the hardware interface. It receives serialized data from the Python script and translates that information into precise PWM signals for the servos.
- **Hybrid Communication:** The seamless link between the Python vision logic and the Arduino hardware allows for near-zero latency, resulting in a bionic hand that mirrors the user's movements instantly.



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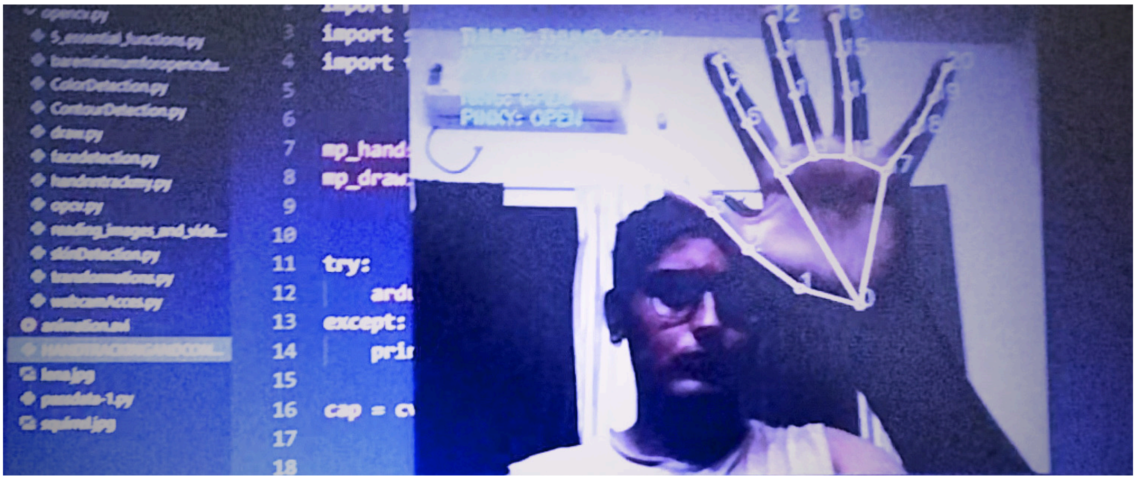
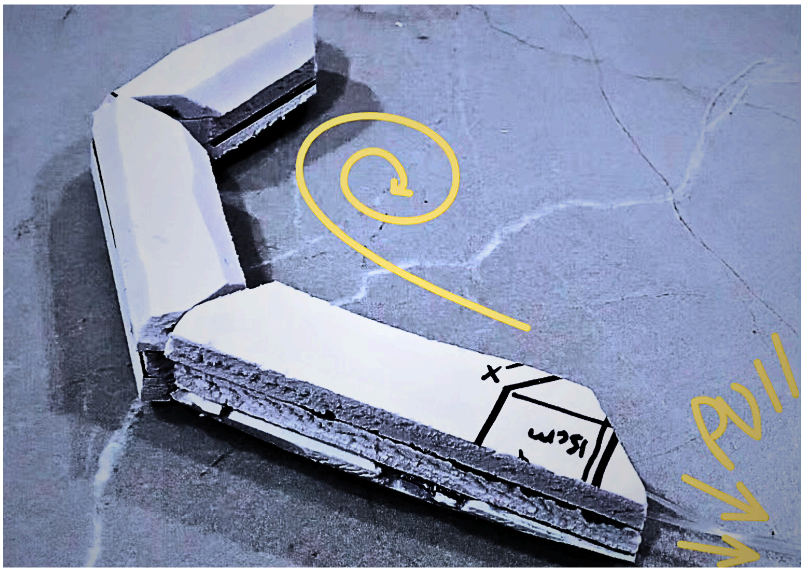
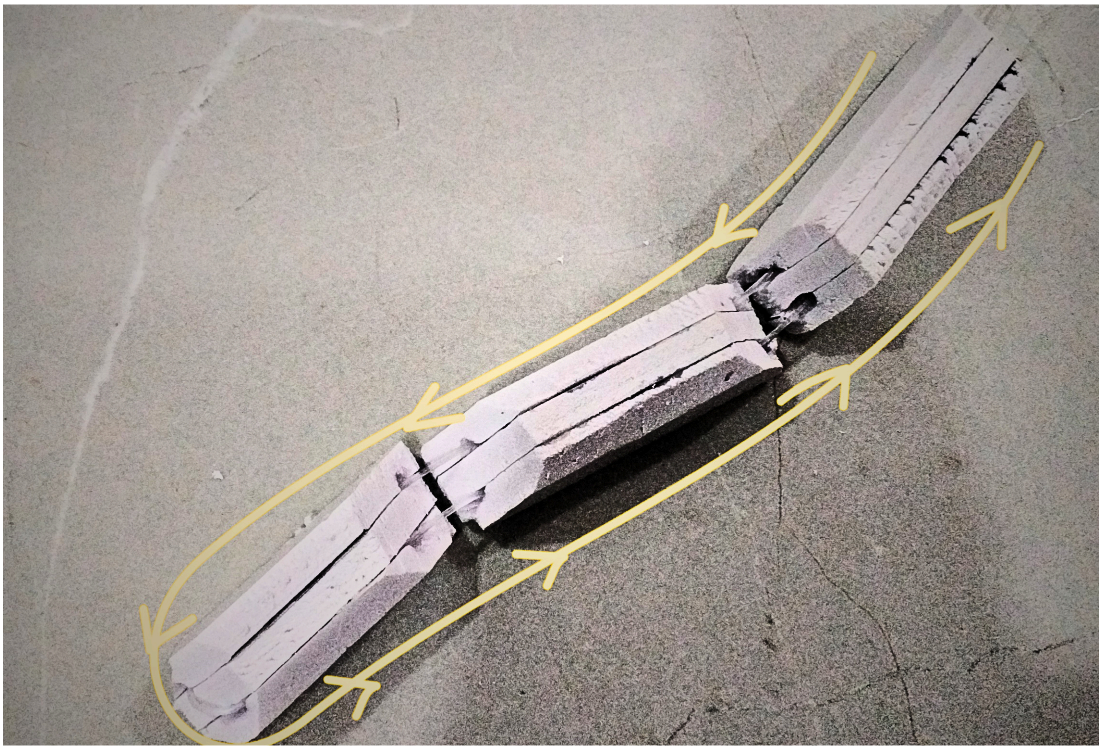


Bio-Mimetic Design & Tendon-Driven Integration

Mechanical Biomimicry The core design philosophy of **Bionic Hand Version 1** is the replication of human anatomy through simplified engineering. Rather than using traditional mechanical hinges, I developed a **Tendon-Driven System** that mimics the way biological muscles and tendons operate:

- **Anatomic Tendon Routing:** I utilized high-strength **fishing line** as synthetic tendons. These are routed through dual-channel holes in each finger segment, mirroring the placement of the *Flexor Digitorum* tendons in a human hand. This allows the hand to curl naturally as tension is applied.
- **Passive Extension (Elastic Ligaments):** To return the fingers to an open position, I integrated **rubber tensioners** on the dorsal (back) side of the hand. These act as "elastic ligaments," providing the necessary counter-force to reset the hand once the servos release the tension, ensuring a fluid, life-like cycle of movement.
- **Geometric Articulation:** Each finger segment was hand-carved into a **trapezoidal profile**. This specific geometry was calculated to allow the segments to fold into a tight, natural grip while providing a solid "mechanical stop" when the hand is fully extended, just like a human knuckle.





Functional Form & Ergonomics The physical build prioritizes a **slim palm profile** and realistic finger proportions. By keeping the palm thin and the structure lightweight, I reduced the rotational inertia and the torque required from the **MG90S servos**. This optimization ensures that the hand can respond instantly to the Python-based vision tracking, creating a seamless, "mirror-like" interaction between the user and the prototype.

The resulting "skeletal" look is a direct reflection of the hand's internal mechanics, emphasizing the elegance of a system where every part has a clear biological purpose

Cost Analysis (INR) Materials Used

Component	Cost per Unit	Quantity	Total Cost
Arduino UNO (Microcontroller)	259	1	259
Laptop Camera (As Vision Sensor)	0	1	0
MG90S Servo Motors	120	5	600
Structural Material (Sunboard/Foamboard 25 inch * 20 inch)	125	2(Approx)	250
20 Meter Nylon Fishing Line	129	2	258
Electrical Tape	20	3	60
Battery Holder (2S)	30	1	30

1200mAh Rechargeable Batteries, 3.7V Lithium-ion Battery	60	2	120
USB-C to 8.4V 2S 1A Step-Up Boost Charger Board for 7.4V LiPo Li-Ion 18650 Battery Power Supply Type-C Charging Module	175	1	175
Jumper Wire	15	15	225
18 - 21 AWG Wire Red 1 Meter	60	1	60
18 - 21 AWG Wire Black 1 Meter	60	1	60
3 inch Rubber Bands	5	10 (5-palm, -Finger Segments)	50
Sand Paper	10	1	10
LM2596 Buck Converter Module	60	1	60
Total			2,157

Low-Cost Prosthetic Alternatives The primary goal of **Bionic Hand Version 1** is to democratize assistive technology.

- **Global Accessibility:** By keeping the total build cost under **₹2,500 ($28 USD)**, this design provides a functional solution for individuals in developing regions where professional prosthetics are financially inaccessible.
- **Rapid Prototyping for Amputees:** Because sunboard is easy to cut and shape, the hand can be custom-fitted and modified by the user in minutes, allowing for a personalized fit without industrial machinery.

Non-Contact Remote Interaction (Tele-Robotics) Currently optimized for a **1-meter (5-foot) range** via a laptop sensor, the project serves as a foundation for long-distance remote operation:

- **Global Tele-Operation:** My roadmap for Version 2 includes integrating **Internet-linked camera modules**. This will allow a user to control the bionic hand from anywhere in the world, enabling "Remote Presence" where a specialist in one country could manipulate objects or provide demonstrations in another.
- **Sterile Medical Assistance:** In environments like surgery or high-tech labs where physical contact must be avoided to prevent contamination, my vision-controlled system allows for the manipulation of tools with zero physical tethering.

Safety & Educational Utility

- **Hazardous Material Handling:** Because the sunboard structure is so affordable, the hand is "sacrificial." It can be used in dangerous environments—such as near mild chemical spills or sharp objects—where a human hand (or an expensive metal robot) shouldn't go. If it breaks, it can be rebuilt for less than $30.
- **Anatomy & STEM Education:** The transparent, tendon-driven design makes this an ideal educational tool. It allows students to visually track how Python logic translates into "biological" movement, making the intersection of AI and Anatomy easy to understand.

Conclusion: The Path Forward

Bionic Hand Version 1 is more than a first project; it is a proof-of-concept for **high-utility, low-cost engineering**. By combining the accessibility of sunboard with the power of computer vision, I have created a system that mimics human movement for a fraction of the market cost.

Looking ahead, I plan to transition from a laptop-based sensor to an **independent camera module with IoT (Internet of Things) capabilities**. This upgrade will remove the 1-meter distance constraint, allowing for global tele-operation and more robust industrial applications. My journey from a student with a sheet of sunboard to a robotics innovator starts here, proving that the only limit to technology is our own resourcefulness.

Conclusion & Future Vision

The Engineering Journey Bionic Hand Version 1 is the result of two months of intensive trial, error, and iteration. This project was not built in a single session; it was developed through a cycle of mechanical failures and software bugs that pushed me to understand the "why" behind every component. From calibrating the **OpenCV-based vision tracking** to perfecting the **trapezoidal geometry** of the sunboard fingers, every challenge became a lesson in resourcefulness.

The Breakthrough The most defining moment of this project was the transition from code to physical motion. After weeks of troubleshooting the **serial communication** between Python and the **Arduino UNO**, seeing the bionic hand mimic my own gestures for the first time was a powerful validation. It proved that a high-functioning robotic system could be realized on a strict **₹2,500 budget** without the need for expensive 3D printers or industrial sensors.

Looking Ahead: Version 2.0 This prototype is a foundation for future innovation. My roadmap for the next iteration includes:

- **Global Tele-Operation:** Upgrading from a local laptop sensor to an **IoT-enabled camera module** to allow control from any distance via the internet.
- **Independent Articulation:** Refining the tendon-driven system to support independent movement for all five fingers, enabling complex "precision-grip" tasks.
- **Advanced Materials:** Incorporating 3D-printed joints to test higher load capacities while maintaining the lightweight "slim-palm" profile.

This project has solidified my commitment to robotics. It stands as proof that innovation is not defined by the expensive tools you have, but by the persistence to keep building until a vision becomes a reality. My journey as a 16-year-old maker has only just begun.

Thank You