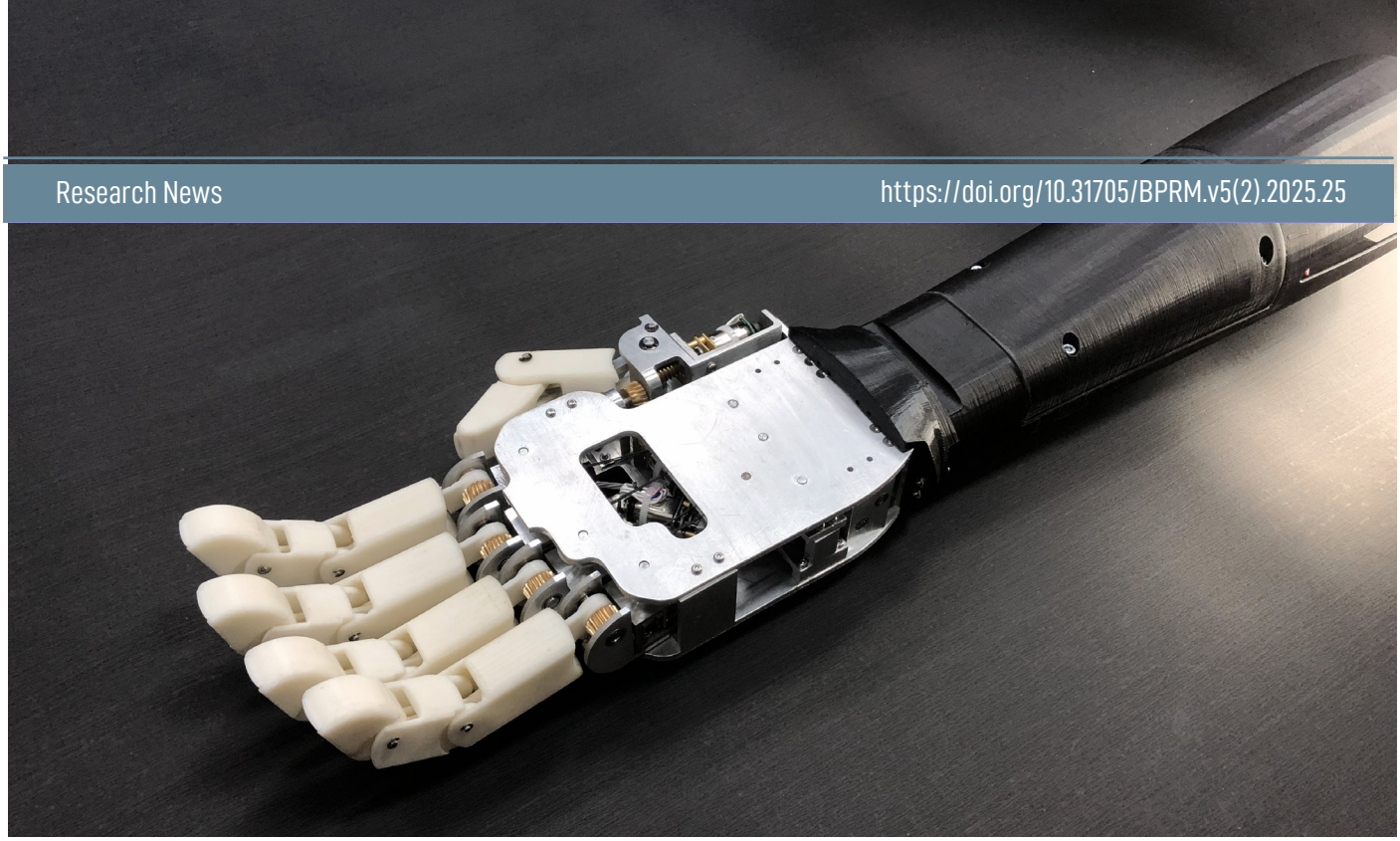
https://doi.org/10.31705/BPRM.v5(2).2025.25



Enhancing Daily Life:
A Prosthetic Hand with Finger Abduction and Adduction

> The proposed anthropomorphic, shape adaptive and underactuated prosthetic hand is capable of individual finger abduction and adduction using a novel cam-driven mechanism

The human hand is a remarkable design of nature. Its complexity and dexterity go beyond imagination, combining both functionality and aesthetic appeal that enhance human creativity and daily life. Life without a hand can be mentally and physically challenging, as it affects nearly every activity. Unfortunately, accidents, injuries, and certain diseases sometimes lead to the loss of a hand. Over the years, engineering innovations have aimed to create smart prosthetic hands that not only restore function but also mimic the natural formation of the human hand, offering both aesthetic value and full functionality.

With robotic prosthetic hands, amputees can possibly regain their normal life by restoring both mental and physical abilities. Today, the development of prosthetic hands and related mechanisms is advancing rapidly, marking a new generation of human-like devices. However, there are still notable gaps to address, and no prosthetic hand has yet been able to fully replicate the complexity and functionality of a biological human hand.

Most existing prosthetic hands are capable of performing finger flexion/extension, which support only the basic grasping patterns needed for daily

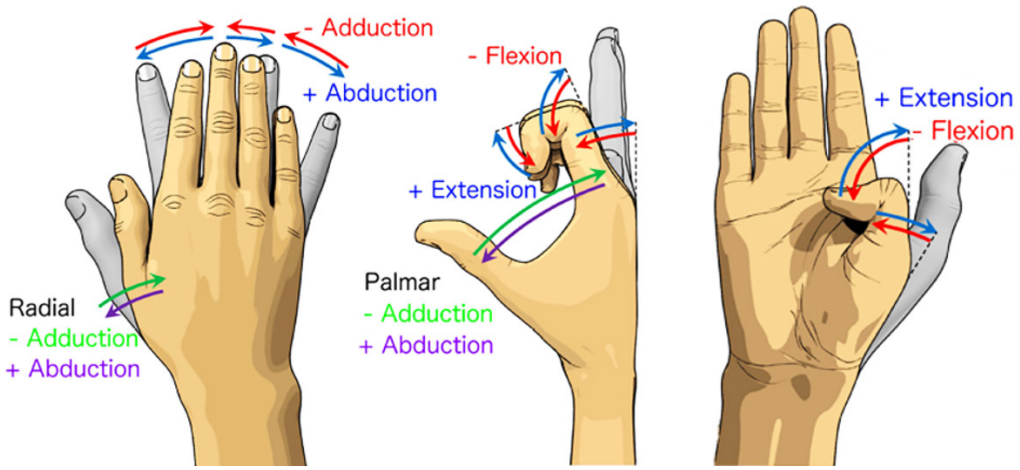


Figure 1 : Basic Finger Movement Patterns [1]

activities. However, advanced designs such as the Pisa/IIT Soft Hand II [2], Dexterous Prosthetic Hand [3], TN Prosthetic Hand [4], and Adab Mora [5] address the other finger motion patterns, especially finger abduction/adduction. The power and precision grasping patterns that rely on finger abduction/adduction cover 65% of grasping patterns used in activities of daily living.

At the Bionics Laboratory, Department of Mechanical Engineering, University of Moratuwa, a robotic prosthetic hand has been developed to closely imitate the natural appearance and movement of the human hand. Weighing only 910 grams and featuring anthropomorphic proportions, it closely resembles a real human hand. The device includes 18 degrees of freedom and uses an underactuated mechanism for flexion/extension. An underactuated system has fewer actuators than degrees of freedom.Article This design also allows finger abduction/adduction—side movements that are often missing in most of the conventional prosthetic hands. As a result, it can perform various grasping patterns, such as tripod (three-finger) and quadpod (four-finger), along with grasping patterns like power and precision grips, providing smoother and more adaptable motion for daily tasks. The goal is to create a prosthetic hand that not only looks natural but also functions similar to a human hand.

Designing a prosthetic hand is a complex task that requires careful balancing of anatomical fidelity, mechanical feasibility, and functional performance. After identifying the research gap, the design process commenced with data collection and mechanism selection. Hand anthropometric measurements were derived from the 50th percentile human body dimension dataset to ensure human-like size and proportion of the prototype. The prosthetic hand uses a common linkage mechanism for finger flexion/extension, while a novel cam-driven mechanism enables finger abduction/adduction.

To ensure the reliability and functionality of the prosthetic hand, comprehensive simulations were conducted during the design phase. Motion analysis was utilized to evaluate the range of motion of each finger and to verify the coordination between flexion/extension and abduction/adduction. Stress simulations were performed on the critical components to assess their structural integrity under applied loads and to ensure long-term durability. Furthermore, a detailed kinematic analysis was carried out to optimize the linkage mechanism and confirm that the prosthetic hand could achieve smooth, human-like motion patterns.

The prototype of the prosthetic hand was manufactured using CNC machining and 3D printing technologies. There are eight motors to control the hand; five of them are allocated for the finger flexion/extension. The abduction/adduction mechanism has two motors for gear mechanism and camshaft, and the thumb finger has one motor for thumb abduction/adduction. The coordination of eight motors posed a significant control challenge, yet it enables the prosthetic hand to achieve a wide range of grasp patterns with high precision.

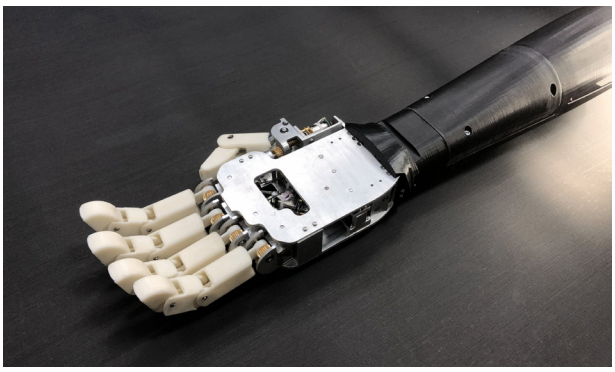


Figure 2: Prototype of Prosthetic Hand with Novel Abduction/Adduction Mechanism

By combining smart mechanical design, strong materials, and precise motor control, the proposed prosthetic hand can help amputees achieve more natural and flexible gripping patterns. The extended functionalities will improve the daily independence and quality of life of the hand amputees. The proposed design further facilitates future upgrades, such as the incorporation of sensors, bio-signal–based control strategies, and intelligent systems, to achieve more natural and responsive hand movements.

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