The Dexios Hand: *Towards Affordable and Functional Prosthetics*

"The Dexios Hand was built to test pioneering advancements in adaptive dexterity, promising a transformative solution for individuals with upper-limb loss seeking enhanced functionality and independence."

Individuals who have experienced upper-limb loss often face significant challenges in regaining functional independence. The absence of a fully functional limb impairs their ability to perform daily tasks, diminishing both their physical capability and overall quality of life. According to global estimates, approximately 20 million people live with upper-limb loss related to traumatic events [1]. Functional prosthetic devices currently available in the market are prohibitively expensive, and lack utility outside of basic grasping actions. This presents a considerable demand for affordable prosthetic solutions that are capable of restoring lost hand function. With this in mind, a research group from the Department of Mechanical Engineering at University of Moratuwa have developed an upper-limb prosthetic device capable of adaptive grasping, employing a novel mechanism to improve dexterity.

The device thus developed, named the Dexios Hand, is a prototype electric hand prosthesis with motorised actuation, which is a more user-friendly alternative to body-powered and cosmetic prostheses. The key characteristics of this functional prosthetic hand are its dexterity and shape-adaptive grasping ability. Dexterity refers to the prosthetic hand's ability to perform skilful movements, while shape-adaptive grasping allows the prosthetic hand to conform to the contours of various objects for a more secure grip. These features are favoured for restoring natural hand functionality in prosthetics since they widen the range of grasps that the device is capable of.

The Dexios Hand's capabilities are due to the use of Joint Mobility Modulation (JMM), which is introduced as a novel technique aimed at enhancing dexterity in myo-electric prosthetic devices, particularly those designed for shape-adaptive grasping [2]. The motivation for developing this method stems from the limitations of previous approaches, which resulted in prostheses

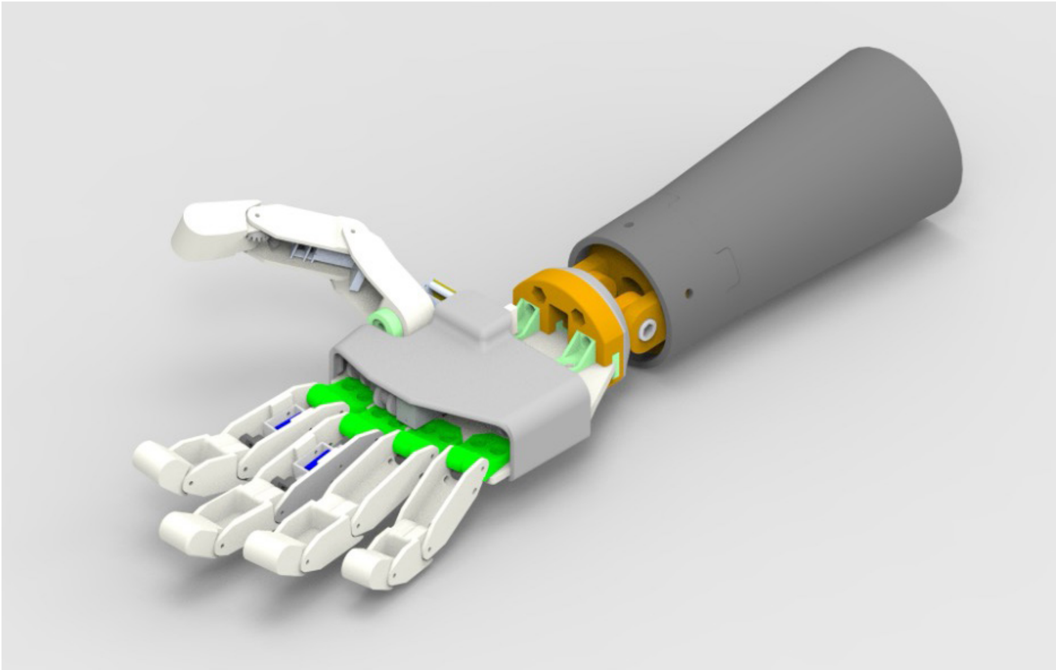

Figure 1: A 3D rendering of the Dexios Hand

that were bulky, costly, and complex while trying to improve dexterity. These drawbacks hindered their potential for practical application in commercial prostheses.
JMM works via the controlled variation of the stiffness or mobility of individual joints within a robotic device. This modulation enables the prosthetic hand to produce a wider range of motions while retaining shape-adaptive grasping abilities. This technique provides a more efficient solution to the dexterity problem, reducing the need for excessive motors or sensors, and consequently lowering the cost and bulk of the prosthesis.

The Dexios Hand provides adaptive grasping capabilities while integrating JMM to improve dexterity. It consists of four fingers, a thumb, a palm, a wrist, and forearm components. Degrees of Freedom (DoF) is understood as the number of independent movements or directions a part of a system can move in, and this device has a total of 11 DoF, with five of these being actively controlled. The structure of the hand is primarily 3D-printed using polymer, with metallic components used in springs and joints, and polymer-mixed thread serving as tendons for movement transmission.

The fingers of the Dexios Hand are underactuated, tendon-driven mechanisms. In an underactuated design, not all joints are independently controlled by motors. Instead, a single tendon is routed through multiple joints, allowing passive motion based on external forces, such as contact with an object. This approach reduces the complexity of the mechanical system while achieving adaptive grasping. Each finger contains guideways for routing the tendons and springs. A unique feature of the fingers is the integration of solenoids in the second joints of the index and middle fingers, enabling basic JMM. Through this mechanism, the joints can be locked selectively based on input from the grasp controller, enabling a wider array of movements.

The thumb features two actuated DoF, facilitating flexion (bending) and opposition (movement across the palm). Unlike the fingers, the thumb is directly driven by motors. The palm serves as a structural component, housing the motors and some spring elements that are connected to the fingers. The wrist of the Dexios Hand has a single passive DoF, allowing for limited motion while maintaining simplicity in design. A slotted feature in the wrist enables easy disassembly for maintenance or customization.

The Dexios Hand is operated through a combination of high-level and low-level controllers. The high-level controller, accessed via an intuitive graphical user interface, parses user intentions

Figure 2: An array of grasping patterns produced by the device

and sends commands to the low-level controller, which directly manipulates the motors to achieve the required hand movements. This layered control system allows for the ease of development of alternative control methods for the device. Presently, the control interface is used solely for demonstration and testing purposes. The electronics system of the Dexios Hand includes a microcontroller responsible for motor operation and communication between the device and a computer. Motor and solenoid controllers manage the actuation of the fingers and thumb.

The device, as it stands now, is singularly a proof of concept for the novel actuation mechanism. Future work on the Dexios Hand will focus on further evaluation, refinement, and development toward a commercial-grade upper-limb prosthesis. Initial testing has demonstrated that JMM significantly enhances the device's operating range, allowing it to grasp a wider variety of objects [2]. However, a more comprehensive evaluation of the grasping ability is necessary. This includes testing the device across different scenarios, object shapes, and user activities to better understand its performance in daily use.

Further testing will also involve refining the design to improve aspects such as durability, power consumption, and reliability. Additionally, in the future efforts to scale the Dexios Hand into a commercially viable product, the research group will put their efforts into optimizing the design and ensuring compliance with medical regulations and standards. By refining the design and making the prosthesis accessible, the goal is to bring a high-performance, affordable myo-electric hand prosthesis to individuals who currently lack access to advanced prosthetic solutions.

References:

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