

## **Development of a highly dexterous robotic hand with independent finger movements for amputee training**

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Around the world, there are thousands of people who lost a hand during war or as a consequence of an accident. Artificial hand prosthesis controlled by surface electromyography (EMG) signals offers a promising solution to improve the quality of life of amputees. As part of the process of prosthesis fitting, an occupational therapist will try to train the amputee with the help of a physical prosthesis [1] that is not actually fitted, but only displayed to provide visual feedback, but these are expensive (>£16,000). This training should be performed for long periods of time at the rehabilitation centre prior to the prosthesis fitting. It aims at improving the generation of nerve signals for capture by EMG probes, and at tuning of the EMG pattern recognition algorithm to the actions most suited for each amputee [2]. This part of the rehabilitation process can be made more efficient and more widely available through the use of a low-cost actuated hand with the same degrees of freedom as the prosthetic device to be fitted.

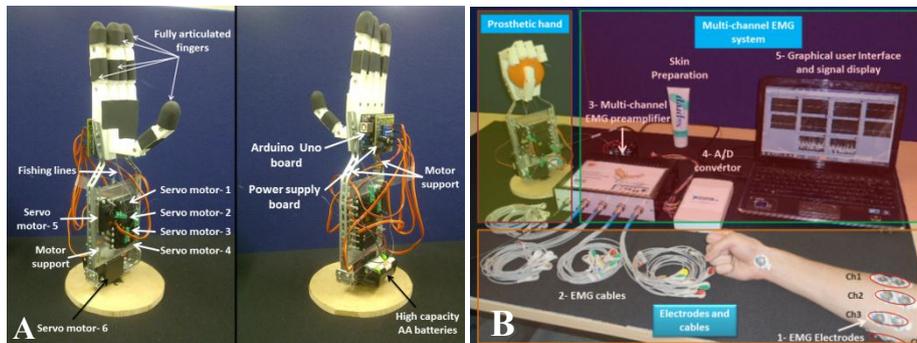
To address this need, a custom-built fully-articulated robotic hand has been developed at Plymouth University. The hand needed to have five fully articulated fingers and the ability to perform hand rotations in 2 directions. In addition, the cost of the hand should be within the margin of £250 in order for it to be affordable for academic and clinical purposes. The robotic hand consists of three main components, the mechanical hand, servo motors and the control unit.

1) The mechanical component of the hand is implemented by rapid prototyping of a 3D open-source hand model (<http://www.thingiverse.com/thing:14986>). A total of 28 parts of the hand were printed by the 3D printer with a highly durable acrylonitrile butadiene styrene (ABS) material at Plymouth University. An extrinsic design was adopted, where the hand is actuated by tendons driven by servo motors located outside the hand.

2) In order to actuate the hand, five tendons were constructed with high-strength (20.5kg) and abrasion-resistant fishing line and were connected to the finger tip of each finger through a groove inside each finger. Highly durable dental rubber bands were used to passively return each finger to its rest position. After finishing the hand design and fabrication, the finger tips were covered with a black rubber material with to facilitate object gripping. Six servo motors (TowerPro MG995) were used to actuate the hand through six tendons. The motors were assembled into a custom-built metal framework and they were connected through the tendon to each of the 5 fingers

(little, ring, middle, index and thumb). A sixth motor was assembled at the base of the mount to rotate the hand in 2 directions. **Fig.1(A)** shows the complete robotic hand with the location of the six servo motors and the components of the control unit. After assembling the motors on the framework, the motors were calibrated to open and close each finger and the initial and final motor positions were recorded for future actuation. The hand can firmly hold objects of moderate weight, such as a cordless drill.

3) The control unit of the hand consisted of two boards, the microcontroller board and the power supply board for the motors. The Arduino Uno microcontroller receives hand posture commands from a PC via the serial port and converts them into commands for individual servo motors. A second board was designed to supply the 5 volts, with current limitation for force control, to the six servo motors. In total, 18 different hand and finger postures were pre-programmed and built into the Arduino. The robotic hand is controlled either with EMG signals via the Matlab interface on the PC [2] or via an electrical switch for a manual selection of the desired movement.



**Fig. 1.** (A) The components of the custom- build highly dextrous fully articulated robotic hand. (B) The complete custom-build robotic hand system controlled with multi-channel EMG.

The total cost of the 3 components of the hand was £232 which is below the estimated budget (£250). This cost is very low compared to the commercially available fully articulated hands and makes possible its widespread use possible for rehabilitation.

This hand can also be used by researchers who are working in the field of myoelectric control. **Fig.1B** illustrates its integration with a custom-build, multi-channel EMG system designed to identify and control a large number of finger and hand movements with EMG signals [2].

### Acknowledgments

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### References

1. Muzumdar, A. 2004. Powered upper limb prostheses: control, implementation and clinical application. Springer, Germany.
2. Al-Timemy AH, Bugmann G, Escudero J, Outram N. 2013. Classification of Finger Movements for the Control of Dexterous Hand Prosthesis with Surface Electromyogram. IEEE Journal of Biomedical and Health Informatics, 17:3, pp. 608-618.