X-Limb: A Soft Prosthetic Hand with User-Friendly Interface

Alireza Mohammadi[1](✉), Jim Lavranos[2], Peter Choong[3], and Denny Oetomo[1]

[1] Department of Mechanical Engineering, The University of Melbourne, Parkville, VIC 3040, Australia
{alirezam,doetomo}@unimelb.edu.au

[2] Caulfield Hospital, Caulfield, VIC 3162, Australia
jim.lavranos@gmail.com

[3] Department of Surgery, University of Melbourne at St Vincent's Hospital, Fitzroy, VIC 3065, Australia
pchoong@unimelb.edu.au

Abstract. We have developed a soft prosthetic hand with features addressing the need of upper-limb amputees using soft robotics techniques. The designed hand is ultra-light and easy to manufacture. It is readily customisable for different hand size due to parameterised CAD design and using 3D printing techniques. The user-friendly control of the hand is achieved by using combination of designed-in behaviour of the finger and optimised movement of the fingers. This enables users to grasp a wide range of objects in one specific hand preshape eliminating the need for multiple switching between different grasps. The performance of the designed hand is evaluated through evaluation criteria used for prosthetic hands.

1 Introduction

The advances in myoelectric hand prostheses showed the potential to return independent living for people with upper limb loss. Despite the recent advances, the heavy weight of the prosthetic hands and lack of user-friendly control of the hand are still major shortcomings [1]. The weight is a major problem causing not only fatigue but also potential damage to the remainder of the body. The lack of non-fatiguing command interface in multifunctional prosthetic hands is also one of the main factors that significantly affects their acceptability. Currently, state-of-the-art prosthetic hands are controlled through electromyographic (EMG) signals using surface electrodes due to their non-invasive nature and long-term stability. Since extracting more than two reliable EMG signals from the residual muscle contractions required more complicated methods, current sophisticated commercial prostheses such as Bebionic are relying on only these two signals to provide 17 grasps and postures. This results in the increase of control complexity, long training periods and unnatural command interface such as using complex

This work was supported by Valma Angliss Trust.

L. Masia et al. (Eds.): ICNR 2018, BIOSYSROB 21, pp. 1–5, 2019.
https://doi.org/10.1007/978-3-030-01845-0_16

timing and pulse sequences of the required EMG command signals, or using the other (able) hand for preshaping the prosthesis.

In this study we conducted the design of the X-Limb with focus on a low complexity and user-friendly interface, to allow robust and reliable control in addition to light weight. This is done by firstly focusing on providing only the most common grasps for the activities in daily living and secondly using 3D printing techniques to manufacture the overall hand with low infill in the structure to reduce the weight.

2 Method

As shown in Fig. 1, we have realised the two most commonly used grasps: pinch grasp and power grasp. Combined, these grasps will cover more than 70% of the daily activities as reported in [2]. In pinch grasp, thumb moves to the abduction position and the index finger moves with the slower displacement (per unit change in EMG command) and they will meet in the 'centre' to form the tip pinch. In power grasp, all fingers will move together with the same speed to full flexion position. Considering the underactuation and compliance features of the hand, the actuation system of the hand consists of five DC motors for flexion of each finger. There is no return tendon in the fingers and compliant flexure joints returns the finger to the original position.

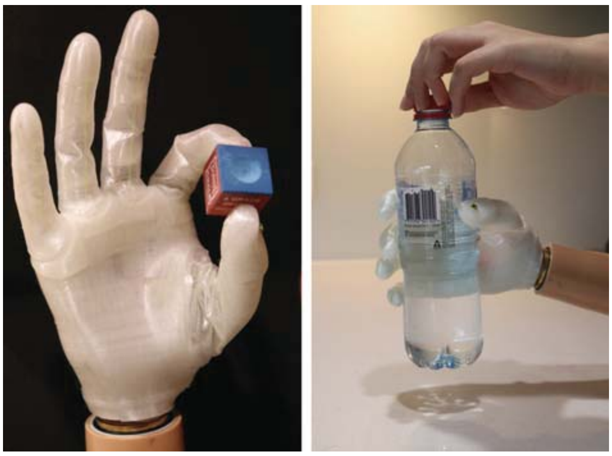

Fig. 1. X-Limb prosthetic hand with pinch grasp (left) and power grasp (right)

Fingers of the hand are designed using flexure joints and hinges with monolithic structure. Monolithic manufacturing eliminates a good portion of the need for assembly and the inadvertent misalignments associated. Furthermore, flexure based articulation provides little friction losses, continuous displacement and a relatively light-weight and compact design. Compliance in the joints also improves the adaptability to the objects being manipulated (potentially improving grasp robustness), highly simplifies the mechanical design and enables safe interaction with humans. Thumb design is done with one flexure joint instead of two to provide stable structure for pinch grasp. The axis of rotation of the thumb is designed in such a way that by pulling the cable moves the thumb from adduction to abduction position. This eliminates the need for adduction and abduction of the thumb for different grasps and therefore simplifies the overall structure.

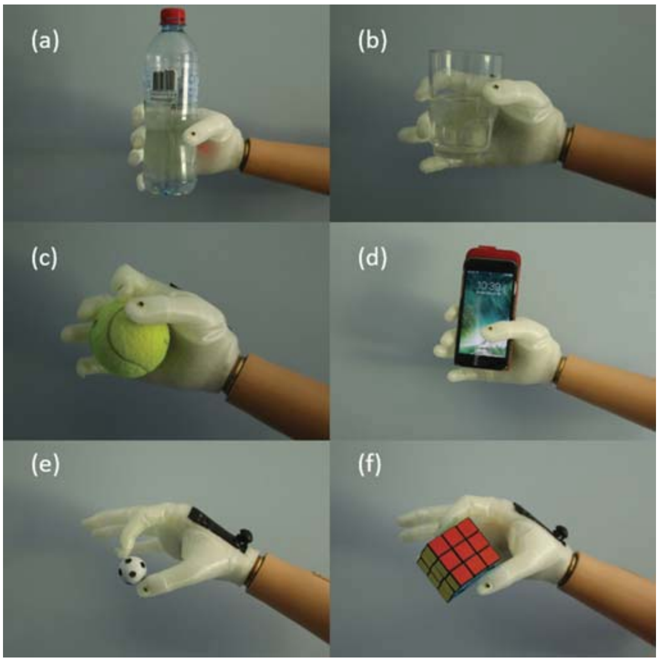

Fig. 2. X-Limb performance in grasping wide range of objects with only two grasp types: power grasp (a, b, c, d) and pinch grasp (e, f).

The transmission mechanism from motors to fingers is tendon. Actuation configuration is intrinsic and all the actuators, motor drivers and the controller are embedded in the hand structure as shown in Fig. 2. The hand is controlled by using only two sEMG (surface electromyography) signals provided by most of commercial EMG electrodes for opening and closing the hand and one simple tactile button located below the thumb towards the back of the hand to switch between pinch and power grasp. An average male hand size (breadth 9 cm and length 19 cm) is adopted in the design of hand.

The X-Limb is specifically designed and customised for fabrication using additive manufacturing techniques and 3D printing of soft material. Additive manufacturing allows realisation and fabrication of complicated features (e.g.

hollow space) which are not possible with conventional manufacturing methods. For fabrication of the whole hand, we used a commercially available 3D printer (FlashForge Dreamer) to print TPU90 (Thermoplastic Polyurethane with Shore 90A).

In order to have a stable pinch grasp while keeping the mechanism simple, a designed-in feature is considered in design of the index finger and thumb. This feature is the air bubble in fingertips of index and thumb. The air bubble is a thin layer of TPU printed on the fingertip to increase the interaction between fingertip and objects in pinch grasp.

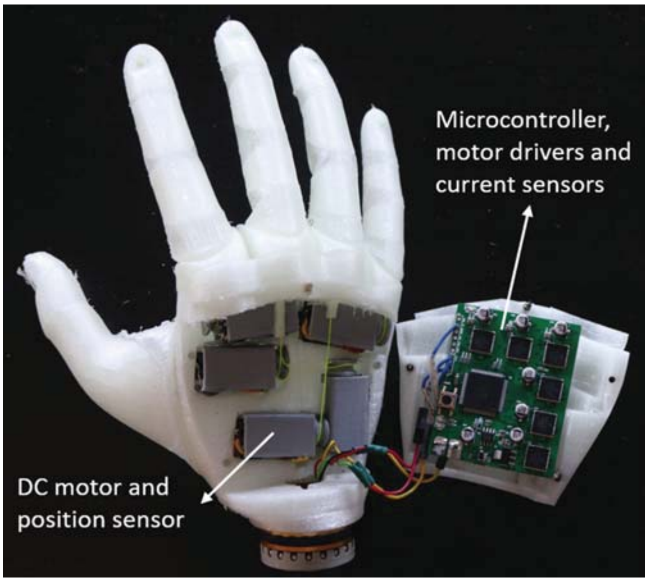

Fig. 3. X-Limb actuation mechanism

3 Results and Discussion

The overall weight of the X-Limb hand including the embedded actuators and universal quick disconnect wrist is 292 g which is half of the weight of existing commercial hand prostheses such as Bebionic. The required functionality for the hand is determined through evaluation criteria for prosthetic hands proposed in [3]. This includes a set of tasks for food preparation, dressing, holding cup, pouring bottle water, opening cap of bottles and picking small items. The capability of the X-Limb in grasping different objects and its application in performing ADLs is shown in Fig. 3. A video from the X-Limb demonstration is provided in YouTube (https://youtu.be/vIF9QH0ojzg).

As shown in Fig. 3(b) and (l), in power grasp mode, the X-Limb fingers can adapt to the cylindrical (water bottle) and spherical (tennis ball) shaped objects without requiring specific grip type. This significantly simplifies the prosthetic hand control interface for users and demonstrates effectiveness of the optimally designed hand prostheses. The designed-in air bubbles in fingertips of the index and thumb fingers also allows grasping small spherical objects as shown in Fig. 3(j) and (k).

4 Conclusions

The results of this study showed that X-Limb design is able to address the current issues with the state-of-the-art hand prostheses through the soft robotics techniques. The light weight and simple control interface of the X-Limb would potentially increase the use time and acceptability of the hand prostheses by upper-limb amputees.

References

1. Biddiss, E.A., Chau, T.T.: Upper limb prosthesis use and abandonment: a survey of the last 25 years. Prosthet. Orthot. Int. **31**(3), 236–257 (2007)
2. Mohammadi, A., Lavranos, J., Choong, P., Oetomo, D.: Grasp specific and user-friendly interface design for myoelectric hand prostheses. In: IEEE International Conference on Rehabilitation Robotics, ICORR, pp. 1621–1626 (2017)
3. Resnik, L., et al.: Development and evaluation of the activities measure for upper limb amputees. Arch. Phys. Med. Rehabil. **94**(3), 488–494 (2003)