Development of an Affordable Myoelectric Hand for Transradial Amputees

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ABSTRACT

Upper limb amputations seriously affect a patient’s life by restricting their ability in performing various tasks. Prosthetic hands are considered the primary method to reinstate the lost capabilities of such amputees. However, the presently available prosthetic devices are unable to fulfill the requirements of users due to their excessively high cost, limited functionality, heavy weight, unnatural operation, and complexity. This article presents an affordable and simple control-based myoelectric hand for transradial amputees. The hand setup mainly consists of a self-designed surface electromyography (sEMG) sensor, a microcontroller unit and a five-fingered, intrinsically actuated 3D printed hand for dexterous operations. The developed hand was implemented with proportional control scheme and was successfully tested on five amputees (with missing lower forearms) for performing grasping activities of different objects. Further, the closing time and grip force at the fingertips were also determined for the hand to compare its performance with the commercially available hands.

KEYWORDS

3D Printing, Closing Time, Grip Force, Myoelectric Prosthesis, Proportional Control, Surface Electromyography, Transradial Amputation

1. INTRODUCTION

Out of the total population of upper limb amputees in the world, more than 59% are transradial (i.e., amputation below elbow). The main reasons of their amputation are trauma, industrial or environmental accidents, cancerous tumor in bone and muscles, etc. Also, the majority of upper limb amputees (65%) are reported from rural areas. These amputees require a prosthetic hand that is not only functional but also affordable and easy to handle. Based on the survey of world health organization (WHO) and international society of prosthetics and orthotics (ISPO) more than 80% of below elbow amputees residing in developing countries cannot afford to have functional prosthetic devices (Hamner, Narayan, & Donaldson, 2013; Slade, Akhtar, Nguyen, & Bretl, 2015; World Report on Disability, 2011). Most of these patients are still using the body-powered and cosmetic prosthesis, which are unable to fulfill the needs of
their daily life. Presently available myoelectric hands are capable of reinstating the lost functionality of amputees up to some extent. But their extremely high cost makes these hands inaccessible to amputees who are especially from developing countries. Thus, this research work aims to develop an affordable myoelectric hand prosthesis that can be helpful to transradial amputees (of low-income countries) for executing the basic functions of their daily livings.

Nowadays, the myoelectric prostheses are widely applied for restoring the lost capabilities of amputees using sEMG signal from their residual limb. It essentially comprises: (i) an EMG detecting device (ii) a controller which processes these signals and translates to control command to drive actuators by employing real-time learning (iii) a prosthetic hand with proper actuation scheme (Asghari Oskoei & Hu, 2007; Parker, Englehart, & Hudgins, 2006). The quality of the myoelectric signal for prosthetic hand control mainly depends on the conditioning circuit of the surface EMG acquisition system (Shobaki et al., 2013).

There is a rapid growth in the research and development of biomimetic prosthetic hands in the last five years. A significant amount of work has been done by the researchers regarding the development of EMG controlled anthropomorphic hand which can provide the features like fine grasping, individual finger movement and prehension force control (Borisov, Borisova, Krivosheev, Oleynik, & Reznikov, 2017; Cipriani, Controzzi, & Carrozza, 2011; Wang, Lao, & Zhang, 2017; Williams & Walter, 2015). However, the end products are still confined to research laboratories only. The main reasons are the size, weight, complexity, and operating speed, which led to the rejection of these devices from amputees. Tact from Idiap Research Institute, Dextrus from open hand project and Ada Hand from Open Bionics are some of the open-source prosthetic hands based on 3D printing technology which can provide low-cost solution to amputees (“Ada V1.1 Assembly Instructions,” 2016; “The Open Hand Project - Dextrus,” 2014; Slade et al., 2015). I-limb quantum (touch bionics), Bebionic v3 (RSL stepper), Vincent evolution 3 (Vincent systems), and Michelangelo (Ottobock) are some commercially available myoelectric hands which are capable of providing more than 5 degrees of freedom (DOF) with the precise grasping of different shaped objects. These prosthetic hands are controlled through a pattern recognition scheme based on the input from multichannel EMG devices or other devices like pressure sensing elements, inertial measurement units(IMUs), Hall Effect sensors, mobile phones, etc. (“i-limb quantum 1 Touch Bionics,” 2015; “Life changing myoelectric hand packed with the latest technology - bebionic,” 2015; “Michelangelo prosthetic hand,” 2014; “VINCTEvolution 3,” 2018). These have great features to perform activities of daily living (ADLs) but their cost is excessively high (i.e., priced between $25000-$100000) particularly for the amputees residing in low-income countries. Also, these hands require enormous numbers of training session for their reliable operation. Despite of several advancements in prosthetic technology the patients still prefers to wear a hand which is low-cost, less complex and lightweight. Example of such type of hand is Ottobock sensor hand which is active in the market due to its lower cost and simplicity (“Myoelectric Speed hands,” 2014). The hand is capable of providing
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