Preliminary Results Toward Continuous and Proportional Control of a Multi-Synergistic Soft Prosthetic Hand

Cristina Piazza, Manuel G. Catalano, Antonio Bicchi and Levi J. Hargrove

***Abstract*— State of art of modern hand prosthesis is populated by sophisticate hi-tech poly-articular hands which usually offer a broader set of movement capabilities, with the possibility to control up to 4 or 5 motors and achieve several different postures. Unfortunately these device are not so easy to control. A novel emerging trend is oriented towards a strong simplification of the mechanical design (through i.e. underactuation mechanisms), but still maintaining a good level of performance. A successful example is the SoftHand2 Pro, a 19 Degrees of Freedom (DoF) anthropomorphic hand which, using two motors, can move along two different synergistic directions, to perform either power grasp, precision grasp and index point. The combination of this multi-synergistic prosthetic hand with advanced controls, as myoelectric pattern recognition algorithms, allows to get promising results toward a more natural and intuitive control, introducing novel features as the possibility of a continuous switch between gestures. Preliminary experimental results are presented, demonstrating the effectiveness of the idea.**

I. INTRODUCTION

DESPITE notable advances in technology and research, function of prosthetic hands and satisfaction of users still remain low [1]. The state of the art of prosthetic hands is divided between very simple hook-like systems, easy to control but not anthropomorphic, and more complex solutions, that try to match the functions of human hands [2]. These devices use a combination of multiple motors and are controlled using surface electromyographic (sEMG) sensors. However, the problem of controlling multi-DoF hands is very complex. Novel trends are leading the hand mechanical design towards a heavy simplification of the actuation mechanism. An example is the SoftHand2 Pro [3]. From the control side, a significant improvement over conventional control methods (i.e. co-contraction, smart-phone control) is the use of sEMG pattern recognition control strategy [4], based on the information content and the classification of muscles group to identify different movement intentions. Nevertheless, pattern recognition strategies used to control commercial prosthetic hands still requires the full re-opening of the device in order to switch between different grips. In this paper we propose an approach that, combining the SoftHand2 Pro with a myoelectric pattern recognition control, allows to get the control more intuitive, through a continuous switching between gestures. The system was preliminary tested on 6 able-bodied subjects.

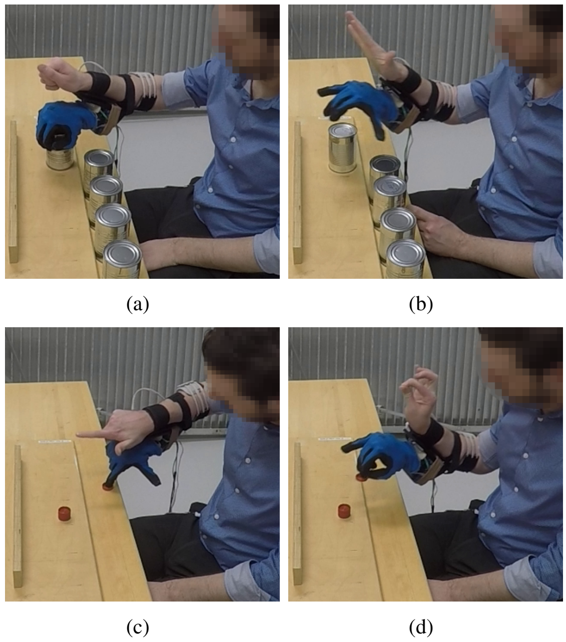

Fig. 1. SoftHand2 Pro used by an able-bodied subject during the JTT experiment. The pictures show the main hand postures: power grasp (a), hand open (b), index point (c) and fine pinch (d).

II. MATERIAL AND METHODS

SoftHand2 Pro is an anthropomorphic robotic hand with 19 DoF evolving the Pisa/IIT SoftHand [5] by the introduction of a friction mediated Degree of Actuation (DoA). The hand is actuated using a single tendon that moves from the palm base through all the fingers and two motors, placed on the back of the hand. While keeping strong similarity with the SoftHand original design, the additional actuation mechanism equips the SoftHand2 Pro with various novel skills, such as good level of dexterity and in-hand manipulation capabilities. To test the extended functionalities of the novel prototype and check the possibility of applying it over the prosthetics contexts, a myoelectric pattern recognition using linear discriminant analysis (LDA) classifiers [6], was used to operate the SoftHand2 Pro in a natural and intuitive way.

Two different control modalities were implemented and

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C. P. is with the Research Center "Enrico Piaggio", University of Pisa, Pisa, Italy (corresponding author: cristina-piazza@ing.unipi.it).

M. G. C. Author, is with Soft Robotics for Human Cooperation and Rehabilitation, Fondazione Istituto Italiano di Tecnologia, Genoa, Italy.

A. B., is with the Research Center "Enrico Piaggio", University of Pisa, Pisa, Italy and Soft Robotics for Human Cooperation and Rehabilitation, Fondazione Istituto Italiano di Tecnologia, Genoa, Italy.

L. H., is with the Center for Bionic Medicine, Shirley Ryan AbilityLab, Chicago, IL, USA, the Department of Biomedical Engineering, Northwestern University, Evanston, IL, USA and the Department of Physical Medicine and Rehabilitation, Northwestern University, Chicago, IL, USA.

tested:

- Control 1 (used as a benchmark), that consist on the full re-opening of the hand to switch between one class to another. This modality is used in commercial prosthetic device controlled using myoelectric pattern recognition.
- Control 2: a novel control modality that allows to switch in a continuous way between one gesture and another, without the need to full re-open the hand and in a more natural way.

Thanks to the intelligence embodied in the design of the SoftHand2 Pro, a continuous switch control between pinch grasp and index point allows also to implement in-hand manipulation skills, without the introduction of an additional class. To test the effectiveness of the novel solution each control was tested on 3 able-bodied subjects. The following experiment was approved by the Northwestern University Institutional Review Board and all participants gave their informed consent. Each subject was wearing a cuff, embedded with eight equally-spaced pairs of stainless steel dome electrodes and one reference electrode, and a wearable mechanical interface to connect the SoftHand2 Pro to the human operator forearm. The classifier was trained with three repetition for each class, selected choosing the hand movements that more closely matched the movements performed by the SoftHand2 Pro: hand open, power grasp, fine pinch and index point.

III. RESULTS

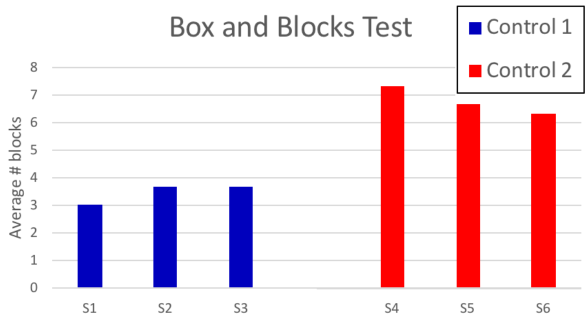
The experiment consisted of two sessions held on two different days. On the first day, after 1 hour and 30 minutes of training, the subjects were performing the Box and Blocks Test (BBT) [7] in three repetitions of 1 minute. The second day, the hand functions for activities of daily living were evaluated through the Jebsen-Taylor Hand Functional Test (JTT) [8]. This test consists on 7 sub-tasks and were started after an initial training of 15 minutes. The results, showed in Fig. 2, demonstrate the effectiveness of Control 2 (in red) compare to the classical control method (in blue).

IV. DISCUSSION

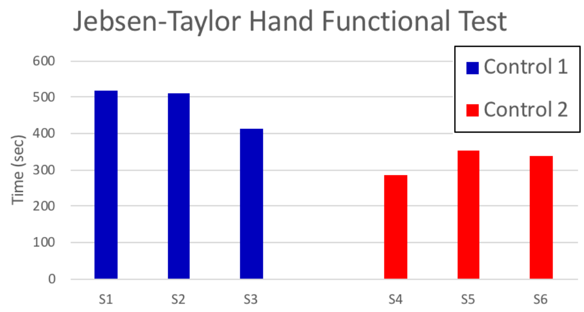
Results from the preliminary test of the continuous switching control on the SoftHand2 Pro were quite satisfactory and interesting to show the potentiality of the system. Control 2 allows to be faster and more natural in grasping, reaching (in average) of double of the performance in BBT (allowing in example to move a block using the index point and switch directly to power/pinch to grasp it) and requiring less time to complete all the JTT sub-tasks.

V. CONCLUSION

This paper presents a multi-synergistic prosthetic hand, the SoftHand2 Pro, controlled using pattern recognition algorithms. A continuous switching control was implemented and compered with the classical control method used in commercial devices. Some preliminary promising results on able-bodied subjects are presented in the paper. Future work will be addressed on the validation of the system on amputee subjects.



(a)



(b)

Fig. 2. Results of the BBT (a) and JTT (b) using Control 1 (in blue) and Control 2 (in red) on six able-bodied subjects (three for each control). The score of the BBT is the average score of the three repetition of 1 minute, while for the JTT the total time required to complete all the sub-tasks is reported.

VI. ACKNOWLEDGMENT

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