# Development of a Sustainable and Ergonomic Interface for the EMG Control of Prosthetic Hands

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**Abstract.** Most of the interfaces of the current upper limb prosthetic device are rigid. However, human limbs and body are a combination of rigid and soft parts. Such a combination inherently suggests to implement soft ergonomic interfaces between the human body and such prosthetic devices. To this aim we have developed a novel set of wearable solutions, including a textile sleeve embedding EMG electrodes for the control of hand prosthesis. This interface has been integrated and preliminary tested in order to control a 5 d.o.f. low cost robotic hand.

**Keywords:** Textile wearable human-machine interface · EMG textile electrodes · Upper limb prostheses

## 1 Introduction

In 2008, about 3 million people in the world were affected by arm amputation, due to congenital, tumors and other diseases. The occurrence of traumatic event is the main cause of these amputation with a percentage rate of 77%. According to the National Center for Health Statistics, every year in the only USA, there are about 50,000 new amputations. Focusing on upper limb amputation in humans, it should be noticed that the human hands are certainly one of the most dexterous and versatile parts of the human's body. Performing daily life tasks without the hands is really demanding and it causes a lot of deficiencies. Therefore, it is mandatory to perform new strategies in order to recover such loss of motor capacities [1, 2].

In this paper we deal with a novel designed interface for the control of a robotic prosthetic hand to help people who have lost their own limbs. There are already plenty of different prosthetic hands and interfaces on the market. Nevertheless, these systems do not always offer good wear-ability as well as proper anthropomorphic design and sustainability. The development of an affordable system for prosthetic hand that will adapt to the amputees with an improved ergonomic is the main purpose of this work.


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## 2 Architecture

In this work we will focus on the interface between the end-user and the prosthetic device. Nevertheless, the overall project behind this work has required the development of a new robotic hand and of the aforementioned interface. Therefore, for a better understanding of this approach, it is more useful to briefly present the overall architecture and different components of the project architecture. An overview of the proposed approach is reported in the next figure (Fig. 1).

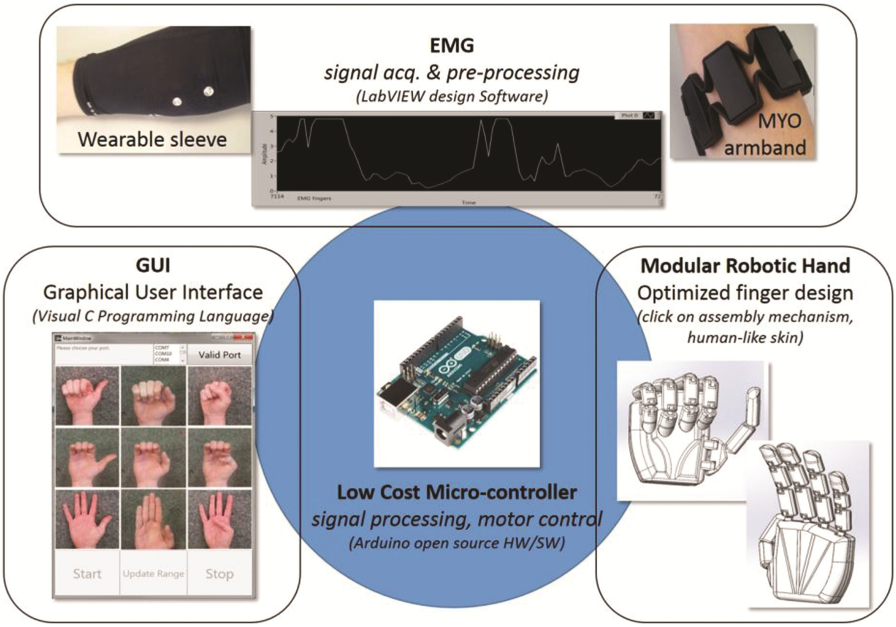


**Fig. 1.** Overview of the project architecture: design of the robotic and prosthetic hand, of its Graphical User Interface (GUI), EMG signal processing and microcontroller programming.

The first element regards the processing of the EMG signals in order to control a robotic hand. This approach quite mimics the natural way of controlling the hand of a healthy subject. In a second element the design of the hardware is considered, namely the development of a novel prosthetic hand. Within this contribution, an important aspect of the design concerns the implementation and the optimization of the fingertips. As soon as the EMG command signals are available, a proper set of functions in order to manipulate and use the signals has to be designed: this role is played from an open source and low cost microcontroller, which commands the motors of the prosthetic hand and read some information from a set of sensors embedded within the hand. Finally, a Graphical User Interface (GUI) is implemented to allow the end-user learning how to use and control the prosthetic hand. The GUI has been designed to display the EMG signals and different grasping configuration that the user can achieve with the robotic hand.

# 3 The EMG Wearable Interface

In terms of EMG signal strategy, the project has been focusing on two approaches, namely two different set of signals which may be used to control the hand.

**Project 1 -** In order to contain the cost of the prototype, we assume to be able to control the robotic hand with a 2-dimensional EMG input, according to previous literature where it has been shown that most of the daily grasping activity can be detailed with two PCs (Principal Components) of the finger angular displacements of human grasping. That means a less number of EMG electrodes may be used to control the hand which will benefit in terms of simplicity of the use, irrespective of the hand dexterity [3–5].

**Project 2 -** In a second stage of the project, we face the possibility of using more electrodes to control the robotic hand. This approach was based on the usage of a pack of electrodes which offers more possibilities in terms of signal classification and future developments.

These two approaches required the design of specific and different software, even if some common elements have been preserved within both the setup. Therefore, within each of the following paragraph, specific requirements related to each approach wil be distinguished.

## 3.1 Optimization of the EMG Electrodes Position vs. Muscles Sites

Generally speaking, the control of a prosthetic hand may be performed by contracting any muscle of the body. However, controlling a prosthetic hand by improper muscles is not really practical. According large literature, the best choice to control hand prosthesis is to focus on the muscles of the subject forearm. According to the number of the used electrodes, the following muscles were recruited through these electrodes.

**Project 1 -** in order to select two muscles or groups of muscles which have to be controllable independently, the locus of the *abductor pollicis longus*, *extensor pollicis brevis* and *extensor pollicis longus* was chosen for the first electrode, since this group of muscle is only activating with the thumb movement [6]. The second locus was chosen in correspondence of the *flexor carpi*: this area refers to muscles that are only contracting when the other fingers are moving (i.e. all fingers except the thumb) [7].

According to the level of the amputation, some of these muscles may be not available. If this is the case, we should clearly refer to another muscular strategy.

**Project 2 -** in this application we will used six electrodes of a commercial product, namely the Myo Armband bracelet that will mainly collect the signals of all the flexor muscles of the forearm [8]. Interestingly, all muscle activities will be captured and transmitted in six different cluster of signals, according to the design of the interface.

## 3.2 The EMG Wearable Interfaces

Different surface electrodes were used, since the needle electrodes are quite invasive, may cause some pain and safety issue.

**Project 1 -** The first type of used electrodes was the H124SG [9], which are really useful because they are easy to place and allows us to make some tests to better know where is the most appropriate place to place the electrodes. Moreover, the signal from these electrodes is quite clean from movement artefacts. Unfortunately, these devices have a limited lifetime and are not reusable. Therefore, a novel EMG sleeve interface was conceived and designed in order to make the electrodes reusable. The sleeve is made of an elastic fabric combined with a DIY "Conductive Fabric Electrodes" which are sewed on the sleeve. Thanks to this manufacturing process the sleeve is reusable and easily wearable. Figure 2 show the inner and outer surface of the sleeve after the preparation on the left and right panels, respectively.

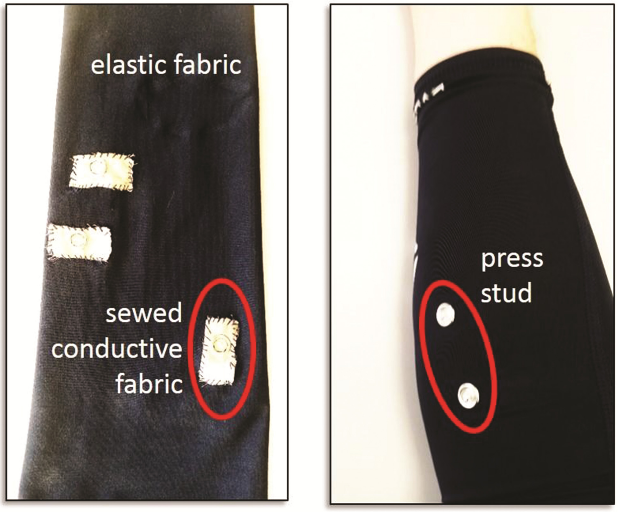


**Fig. 2.** On the left and right panels, the inner and outer layer surface of the homemade & reusable conductive electrodes.

The operational functioning of the device is simple: by sewing the conductive tissue on an appropriate place, we are able to detect the EMG signal. These tissues play the role of the electrodes. The armband is elastic and allows to have a great contact between the skin and the conductive. Some press studs have been attached to the centre of the electrode to perform a click-on mechanism and allow to snap the cables to the electrodes in order to externally transmit the EMG signals out of the wearable sleeve (Fig. 3).

A customized acquisition system based on open source hardware was developed in order to test the system, as well as a dedicated software interface was designed to visualize the signals. The Fig. 4 shows the EMG data output as it was obtained from the reusable electrodes. This visualization was developed under the Labview Design Software (from National Instruments) [10].

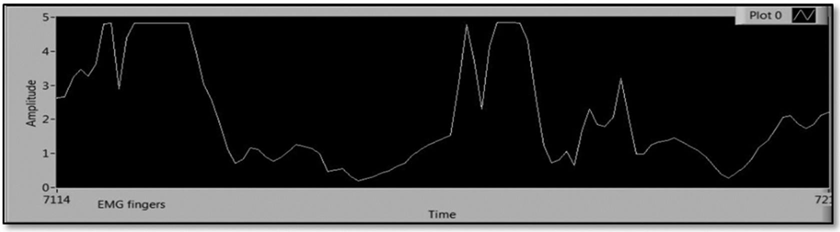


**Fig. 3.** Rectified and amplified signal from preliminary trial with the homemade reusable electrodes

**Fig. 4.** The Myo Armband bracelet

**Project 2 -** As it was mentioned before, another integrated device was used to acquire the EMG signals and control the robotic hand, namely a Myo Armband bracelet embedding multiple electrodes.

This device works with Bluetooth that makes it really portable and design. Moreover, it can recognize different limb gestures which allows to easily interface with the prosthetic hand.

## 4 Data Acquisition System

To be contracted a muscle needs to receive an electrical information from the motor neurons. Such a signal has to be amplified and filtered in order to be used. The Myo Armband already integrates its own amplifier and rectifier electronic board. Therefore, this board will not be discussed here, rather we will detail the prototyping of the amplifier and filter which has been used for the Project 1.

**Design of self-prototyping board** - A data acquisition hardware prototype was designed and realized according to instructions reported on [11]. The final manufacturing is reported in Fig. 5.

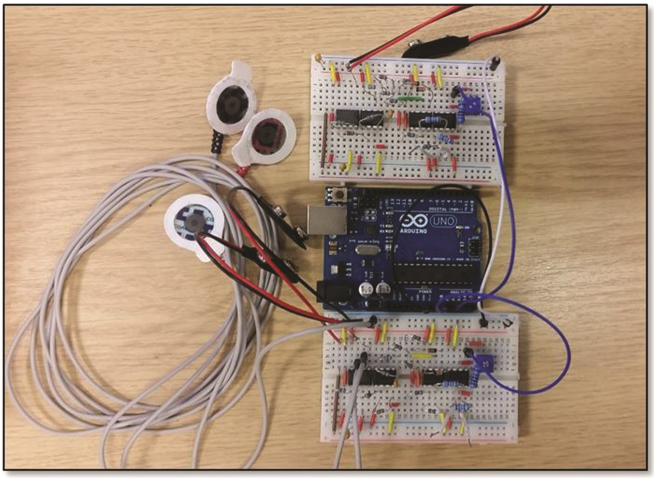


**Fig. 5.** The self-developed data acquisition system

This electronic set-up was finally working properly and it allowed to read two amplified and rectified EMG signals. However, a smaller device would be desirable to be easily integrated within our application.

## 5 Discussion and Conclusion

There are plenty of systems and products, which allow to capture and process the human EMG body signals. However, some of these solutions are currently quite expensive or not really functional. Here we suggest a set of more ergonomic and low cost solutions for better comfort of use in prosthetic applications.

The proposed wearable textile sleeve is an attempt to conjugate a low cost device with good ergonomic optimization. This solution may be combined with open source hardware implementing the signal processing and communication. On the other side, the Myo Armband is a commercial product which allow to control a large number of grasping positions. This product is not so much more expensive than the other solution and offers a lot of possibilities.

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