Innovative Human-Machine Interfaces for Low Cost and High Capacity Prosthetic Hand

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Abstract – This paper proposes building a low cost prosthetic hand with the same functionality of top-line ones that allow the selection of several grasping patterns but with innovative Human-Machine Interfaces (HMI) based on hybrid Electromyography (EMG) with Inertial Measurement Unit (IMU), image processing, Radio-Frequency Identification (RFID) or voice commands. The development of these interfaces is to analyse which combination of HMI suits the best the needs of the users. The reason is to increase the quality of life of upper limb amputees by giving them access to a product with high performance but without the high cost that makes them inaccessible for most Brazilian who needs these prosthesis. As a result, it is expected an open hardware product, easy to maintain, and personalised.

Keywords – Prosthetic Hand, Human-Machine Interface, Electromyography, Inertial Measurement Unit, Image Processing, Radio-Frequency Identification, Low Cost, High Performance

1. Introduction

Amputation is the term used to define the partial or total removal of a limb. This is caused by a number of factors such as diseases or traumatic events (traffic or human accidents). In Brazil, according to [7], is estimated that the corresponding upper limb amputation represents 15% of all the amputations. However, there are no precise information about it within the country. The total amputation procedure performed by SUS (Sistema Unico de Saude) in 2011 were 6% in the upper limbs. It was also stated by [7] that upper extremities amputees may have difficulties to interact with devices that require manipulation skills especially with small keyboards, glasses, or other objects that require the ability to be manipulated carefully.

In order to improve the quality of life of amputees, many high-end prosthetic hands that could be a solution for those people [2], [9], [4] are sold. These technologies have superior set of grasp that allows users to perform most of their daily activities. In addition, high-end prosthetic hands usually have smooth movements because they have up to sixteen degrees of freedom, which allows a precise interaction [6]. Nevertheless, the cost of these prosthesis are high (Bebionic used to cost $11.000 in 2010), making them an inaccessible technology for most of the Brazilian in need. The high cost can be explained because the greater the number of degree of freedom, actuators and sensors a system has, the higher its cost. Also, the prosthesis are made in expensive resistant carbon fibre material and precise quality motors.

Moreover, high-end prosthesis requires from users intensive training to learn how to control the motion of fingers since the action selection is done through a combination of many different muscular contractions. Even though, as indicated in [5], handicapped people need to do less effort and learn quicker how to control electromyography-based systems, the training process might take several months, depending on the level of amputation. Generally, higher the level of amputation, harder the training process is, since the muscles are interwoven in a small place after an amputation surgery, adding difficulty for the user to control them [8].

According to [10], recent research has been emphasised on the improvements of actuation system, control strategies, quality of input signals, and the mechanical design of fingers and hand to try to develop low cost prosthetic hands. Yet, it is necessary to draw attention to the three functional requirements explained in [3] that a machine hand should allow manipulative dexterity, grasp robustness, and human operability. Otherwise, building a low cost prosthetic hand may not be worth the effort since users are likely to give up using the prosthesis as it is not fit for what they need it to do. In fact, [3] also states that one of the reasons why robotic hands are scarce in practical application is the time spent on planning or programming actions that are needed to perform a task. Users must not feel uncomfort-
able while performing any everyday task since the main purpose of the prosthesis should be helping them to be more independent.

Aiming to change the scenario exposed, this paper presents a research proposal to develop a Brazilian low cost and high capacity prosthetic hand that will be firstly tested as a prototype for improvements of the system and then will be offered as an open hardware product to the amputee society to overcome everyday manipulation related problems.

This paper is organised as follows: Section 1 described a brief review of the importance of this study and what researchers are trying to do to solve the described problem. The second section shows the research proposal, followed by a presentation of the expected results in section 3. Finally, section 4 concludes this work.

2. Research Proposal

Studying the functionality of the smart business prosthesis is the first proposal of this research. This is necessary to establish a working basis and have a better understanding of how this project will affect the life of people with disabilities.

A following aim is to develop a low cost prosthetic hand using a 3D printer. This hand will have the same features of high-end prosthetic hands such as Bebionic [2], i-Limb[4], and Vincent hands [11]. The prosthetic hand developed in this project will have smart actuation of the fingers using low cost micro-controllers, sensors, and actuators. In addition, the different actuation modes will be triggered by innovative Human-Machine Interfaces combining hybridly Electromyography (EMG) with Inertial Measurement Unit (IMU), image processing, Radio-Frequency Identification (RFID) or voice commands. These interfaces are necessary to evaluate the simplicity and how comfortable the use of these methods is, as well as the confiability, the reliability and the ergonomic aspects of the prosthetic hand as a product.

It is important to highlight that a framework for robotics simulation will be developed in order to test the actuation modes based on hybrid EMG; this way the development of the real prosthesis becomes independent from the development of the interfaces of actuation. Since the simulation is kinematically equivalent to the real prosthesis, it will be possible to use the same control system that will be used to control the real prosthesis.

3. Expected Results

Regarding the results it is expected to first build a simulation of the prosthetic hand in order to analyse the communication interfaces. It is expected to successfully interpret an IMU and EMG signals that allow the selection of one of the grasp type and display it in the simulation. Table 1 shows some possible combinations in the selection process of a grasp. In this table, R, P and Y are the Roll, Pitch, Yaw angles respectively. The goal is to reach up to 14 (fourteen) possible combinations to allow the selection of most everyday life grasping type and hand use: active index grip, column grip, abduction grip, finger point, hook grip, key grip, mouse grip, open palm grip, pinch grip, power grip, precision close/open grip, tripod grip, and relaxed hand [1].

<table>
<thead>
<tr>
<th>EMG</th>
<th>IMU (R,P,Y)</th>
<th>Grasp</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 contraction</td>
<td>(0°, 0°, 0°)</td>
<td>Finger point</td>
</tr>
<tr>
<td>2 contractions</td>
<td>(0°, 0°, 0°)</td>
<td>Key grip</td>
</tr>
<tr>
<td>1 contraction</td>
<td>(0°, 45°, 0°)</td>
<td>Mouse grip</td>
</tr>
<tr>
<td>2 contractions</td>
<td>(0°, 45°, 0°)</td>
<td>Power grip</td>
</tr>
<tr>
<td>1 contraction</td>
<td>(0°, 90°, 0°)</td>
<td>Hook grip</td>
</tr>
<tr>
<td>2 contractions</td>
<td>(0°, 90°, 0°)</td>
<td>Precision close grip</td>
</tr>
</tbody>
</table>

Table 1. Demonstration of possible activation commands.

More investigation on HMI are envisioned for instance the efficient use of RFID to select the desired grasp or using Google Cloud Vision API for image processing. In this one, the selection of the right position of the hand is achieved by photographing an object, classifying it and, based on the textual description of the image returned by the online API, suggesting the user some set of grasp to interact with the photographed object.

Finally, it is expected to use voice command to select the grasp by saying which one he would like to activate to interact.

All these different modes of interaction will be compared in terms of reliability, comfort, and usability (ergonomic aspects of using the prosthesis). This comparison is going to be based on feedback from users in order to improve the product.

After running all the validation and usability tests, and having a full analyses for the final product, the real prosthetic hand will be built using
3D printer technology and off-the-shelves components in order to allow people with no experience in building prosthesis to be able to build their own customised prosthetic hand at a low cost. Several prosthetic hands projects are using the open hardware concept; however, most of these projects are enabling the prosthesis to only open and close the hand. The main goal of the hand to be developed within this project is that it will have agile control to perform many different types of movements and grasping patterns. Hence, the users will be able to perform most activities of their daily life.

Another characteristic of the prosthetic hand is to be easy to maintain. This way, there will be no problem in changing old components and no specialised staff will be needed (decreasing further costs).

4. Conclusion

In this paper, the importance of the study of upper limb prosthetic hand was shown. Also, some examples of high-end prosthetic hands were presented, as well as the reasons why those products are not widely used in Brazil. To reverse the presented scenario, it was proposed a research that aims at letting upper limb amputees overcome problems they found every day in interacting manually with objects.

This research has as primary goal to study and implement different interaction means in the selection of grasping patterns on a simulation of a smart prosthetic hand. Based on the results from these tests, modification on the prosthesis design will be made and tests with a physical prosthesis is planned to evaluate safety, flexibility, stability, reliability and the comfort of the product.

Finally, any further design modifications on either software or hardware is going to be made based on the tests with patients that have used the prosthetic hand during the tests.

References