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A myographic-based HCI solution proposal for upper limb amputees

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Abstract

Interaction plays a fundamental role as it sets bridges between humans and computers. However, people with disability are prevented to use computers by the ordinary means, due to physical or intellectual impairments. Thus, the human-computer interaction (HCI) research area has been developing solutions to improve the technological accessibility of impaired people, by enhancing computers and similar devices with the necessary means to attend to the different disabilities, thereby contributing to reduce digital exclusion.

Within the aforementioned scope, this paper presents an interaction solution for upper limb amputees, supported on a myographic gesture-control device named Myo. This device is an emergent wearable technology, which consists in a muscle-sensitive bracelet. It transmits myographic and inertial data, susceptible of being converted into actions for interaction purposes (e.g. clicking or moving a mouse cursor).

Although being a gesture control armband, Myo can also be used in the legs, as was ascertained through some preliminary tests with users. Both data types (myographic and inertial) remain to be transmitted and are available to be converted into gestures.

A general architecture, a use case diagram and the two main functional modules specification are presented. These will guide the future implementation of the proposed Myo-based HCI solution, which is intended to be a solid contribution for the interaction between upper limb amputees and computers.

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1. Introduction

Nowadays, computers and similar devices are largely accepted as simultaneously essential and common elements on society's daily routines. In fact, they are used in a wide range of activities, such as personal (e.g. fitness monitoring, leisure), professional (e.g. medical care, financial management, education) and even those involving risk (e.g. clinical patient monitoring, financial decision support). Nonetheless, interaction with the aforementioned technologies may not be accessible to everyone, considering that there are people which have different disability types. Consequently, as a result of the inherent digital exclusion, the lack of access to these technologies can lead to this public's social exclusion¹.

With respect to disability types, physical disability has a particular impact in HCI as it may inhibit the body's ordinary activity, resulting in difficulties while performing interaction tasks. In the specific case of individuals with upper limbs disability, the use of computers and similar devices can be extremely complicated due to the need for inputs that are typically provided by arm-hand-fingers coordination. Upper limbs disability can be originated by several health conditions, such as amputations, cerebral palsy, multiple sclerosis, rheumatoid arthritis and Parkinson's disease, affecting a considerable range of publics². These need an adequate interaction strategy to achieve a successful engagement with technology, especially with computers.

HCI research area includes - but it is not limited to - virtual reality, health, interactive computer games and accessibility³. It provides solutions that support communication between humans and technology through diversified forms of interaction, including speech recognition, gestures and handwritten words⁴. With regard to accessibility, it aims to include people with disabilities in the digital society by combining product design with the impressive capacity that humans have to overcome physical issues by improving the skills of intact or less damaged body parts⁵. As an example, upper limb amputees can develop the physical ability to act more accurately with their legs.

This paper proposes a novel HCI solution for upper limb amputees, based on Myo: a wearable device capable of acquiring electromyographic readings (muscular activity) and inertial data that can be converted into input gestures for interacting with computers. Although being a gesture control armband, we intend to use Myo in the legs, under the assumption that they also have muscular groups which are suitable for gesture inputs.

The remainder of this paper is organized as follows. Section 2 presents the most significant human disabilities that range from visual impairment to intellectual dysfunction, as well as some related HCI solutions. In Section 3, a set of existing HCI devices oriented to gesture recognition will be presented, highlighting the Myo armband, which is the core technology of our solution proposal for upper limb amputees, presented in Section 4. Section 5 provides some final conclusions and directions for future work.

2. Accessible Human-Computer Interaction

According to the International Classification of Functioning, Disability and Health, disabilities are “problems in body function or structure as a significant deviation or a loss”⁶. For each disability type there are different HCI technologies that can be employed to compensate the lack of a specific capability. The following list contains a set of disabilities and how technology can aid to interact with computers or similar devices, in each case:

- Visual disability: through touch or audio (e.g. braille line, voice synthesizer);
- Hearing disability: it does not impose major difficulties in the different interactions, except in using sound;
- Physical disability: interactions are made through the eyes, the voice or over brain-computer interfaces (BCI);
- Disability in the speech: there are no difficulties of interaction, unless voice recognition is necessary;
- Dyslexia: voice systems can be very useful to facilitate reading and writing. Moreover, writing review software can also be advantageous;
- Intellectual disability: these type of limitations do not affect the physical aspect. However, both the software and the hardware solutions that provide support for this kind of users must consider intuitiveness and ease of use².

Physical disability is emphasized in this work due to its restrictive nature when it comes to perform tasks involving computer hardware. Such condition can be defined as a “complete or partial change of one or more segments of the human body, causing in the impairment of physical function, appearing in the form of paraplegia, paraparesis,

monoplegia, monoparesis, quadriplegia, tetraparesis, triplegia, tripareisia, hemiplegia, hemiparesis, amputation or absence of the member, cerebral palsy, members with congenital or acquired deformities, except cosmetic deformities and those which do not cause difficulties for the performance of functions”⁷.

Specifically in what regards the upper limbs, there are several disabilities that affect them either directly or indirectly, as for example: cerebral palsy, multiple sclerosis, rheumatoid arthritis, Parkinson's disease and amputation⁸⁻¹². From these, the upper limbs amputation represents a major barrier for the interaction between a person and a computer or a similar device. Typically, persons who have this disability can experience three damage classes affecting different parts of the limb¹²:

- Hand amputation (including partial hand amputation, transcarpal and wrist disarticulation);
- Arm amputation (including transradial, elbow disarticulation and transhumeral);
- Shoulder amputation (including shoulder disarticulation and scapulothoracic amputation).

To overcome the lack of technological accessibility induced by physical disabilities, several solutions have been proposed within the HCI research area. Fig. 1 presents a diagram that establishes a correspondence between the different disabilities and interaction types. For example, for people with a physical disability the most common interaction types are gesture, voice and gaze recognition. People use voice recognition and gaze (using an eye tracker) when they normally do not have any kind of mobility what so ever. Such devices involve techniques and mechanisms capable of providing reliable communication capabilities between persons (with disability or not) and computers, enabling the exchange of control inputs and responsive outputs.

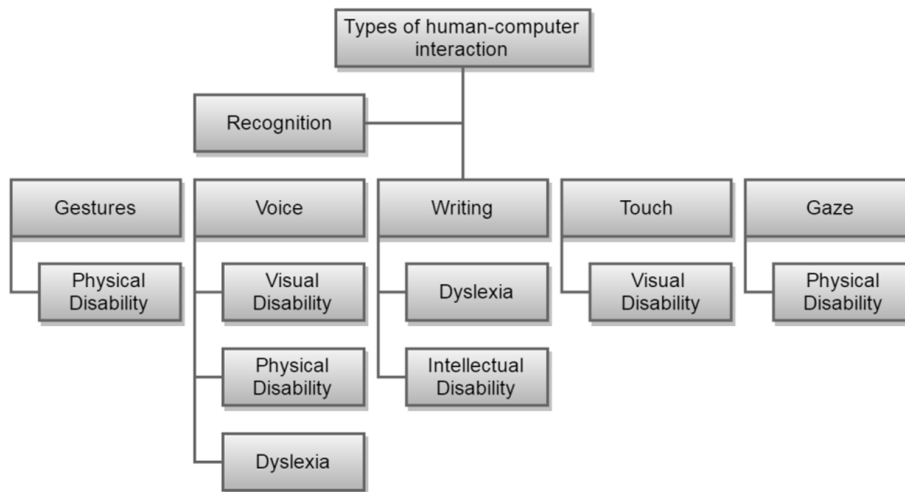


Fig. 1. Diagram depicting the different interaction types used to bridge distinct disabilities. For each disability, there is a HCI strategy that tries to suppress the need of defective human elements (such as senses, the intellect or body limbs), potentiating the use of the healthy ones.

The following subsections will provide a short survey on HCI approaches that include interaction techniques and related devices, covering both the general public and persons with physical disabilities.

2.1. Gesture Recognition

HCI through gesture recognition is the most natural and simple interaction type, because it is identical to the interplay between humans. There are two main techniques to recognize gestures: using electromechanical or magnetic sensors and through digital image processing³. Moreover, it is possible to recognize static and dynamic gestures. The static gestures are considered as different positions of the hands and fingers (eg. open hand, fist, etc.). The various

characteristics of each gesture can simplify its detection. In the capture of a dynamic gesture, the most important is the trajectory that it produces⁴.

2.2. Voice Recognition

Voice recognition consists in the computerized conversion of spoken words into digital text. This interaction is used to write text messages (using, for example, email or short message services) and even to issue computer commands in order to accomplish tasks. However, this interaction technique has still several issues that need to be overcome, including voices differentiation, accentuated vocabulary, emotional gauging, specificities related with location-based vocabulary, among others. Despite voice recognition being able to achieve an impressive success rate of 97%, this interaction technique is mainly used as an alternative in some particular situations, where the use of physical keyboards is not suitable¹³.

2.3. Handwriting Recognition

Handwriting recognition is another method for text input. Its usage metaphor is based on a common and usual handwriting activity. Differences in calligraphy constitute the most prevalent issue in this interaction technique, which has a character recognition effectiveness directly related with the similarity between the writing style and computerized fonts: the more similar, the more effective².

2.4. Touch Recognition

Touch interfaces are closely connected to haptic and kinesthetic interaction. They usually allow computer inputs while the user is touching in devices that comprehend pressure, texture, vibration or/and others. For example, Braille line is a well-known and commonly used device to help blind people interacting with computer systems¹⁴. Texture patterns supply the blind user with the necessary haptics to perform tasks successfully.

2.5. Eye Recognition

Visual contact is used to regulate interaction and to point out interest in a certain viewable target. Both goals can be achieved through eye-tracking: a well-known process for monitoring the human eye, including movements and gazes, in the context of computer scene observation. Underlying the eye-tracking process, there is the eye recognition that is currently managed through several techniques such as video-oculography, video-based infrared, pupil-corneal reflection and electrooculography. The main issue related with the interaction using eye recognition is the required ability to focus with precision¹⁵.

Besides the aforementioned interaction techniques, there are others implemented by devices that range between popularity and novelty. The most common are the mouse and the touchpad. Others, less used, include the trackball, the thumbwheel and the joystick. Usually, these latter interaction devices are used by people with physical disability² who also have available other equipment - for example, eye-tracking, BCI and switches - specifically designed to deal with some particular disabilities¹⁶. The next section will explore further the gesture recognition devices, highlighting an emergent electromyographic-based technology known as Myo, due to its relevance to this work.

3. HCI solutions based on gesture recognition

Upper limb amputees can find it quite difficult to interact with computers and similar devices because they cannot use common input peripherals such as a keyboard or a mouse. There are simpler interaction devices that can be used by people with this type of physical disability, as head pointers, voice recognition systems and gesture recognition through a web camera. Mouse cursor movements, click and double click can also be triggered by a person's mouth and gentle air puffs, that control a straw-like joystick. Moreover, there are also devices that are enabled by the lower

limbs, as pedals and pull-click starters. Software that supports HCI by means of gesture recognition (head movements, for example), gaze (electrooculography) and electromyography¹⁷ is also available.

In the last few years, some interaction devices based on gesture recognition have been appearing, such as: Kinect, DepthSense HTlib, Leap Motion and Myo¹⁸. Microsoft Kinect was initially developed for gaming. It consists of a RGB camera, a depth sensor, accelerometers and a set of microphones for voice recognition. Kinect is capable of detecting up to 48 articulation points of the human body, has a 60% view field and recognizes gestures from different persons by means of digital image processing. Although being able to detect the whole human body, Kinect was particularly designed to follow the hands' movement, which are the most important limbs to be considered in a gesture¹⁹. As for the Leap Motion, its objective is to convert hand movements into computer commands. It connects to a computer via USB and when placed facing up in a given surface is capable to detect an above area with a sensibility to about one meter. This device has some issues, such as motion sensitivity and arm fatigue. Moreover, it does not have predefined gestures, which means that different movements will be used in different applications to perform the same action²⁰. DepthSense HTlib was developed by Softkinetix company for PlayStation4 and its purpose is to improve games' interactivity and realism. Just like Microsoft Kinect, this device operates on the human body recognition field, detecting up to 4 persons simultaneously and up to 21 articulations points per person. The calibration is performed automatically and the device filters out all objects that are not being detected as people²¹.

Myo was developed by a Canadian company called Thalmic Labs, in 2014. It consists in an armband equipped with several sensors - whose purpose is to recognize hand and arm movements²² – and is synchronized with a given computer by means of a Bluetooth 4.0 interface. However, Myo requires a calibration step every time it is used by a different person, due to the morphological differences that describe each arm, with respect to skin and muscle²³. Besides predefined gestures, new ones can be defined²⁴. Regarding the aforementioned HCI solutions based on gesture recognition, Myo has a clear potential to not restrict interaction to upper limbs. Being that the proposed HCI solution for upper limb amputees is based on this device, its discussion will be more extended. Although Myo can be considered a novelty, there is already a considerable amount of work developed around it. A few examples are going to be presented and discussed. Navigating in a map through gesture recognition instead of using a mouse is a project based on Myo developed by Sathiyarayanan and Mulling²³. The authors have concluded that issuing commands with Myo in that context is very difficult. Nymoen *et al.*²⁵, evaluated Myo in a musical interaction context, through the comparison of its components (electromyographic and inertial sensors) against control instruments (BioFlex electromyographic sensors and marker-based optical motion capture). It was found that the detection of electromyographic data through Myo is not the best due to the variation of the arms' size. The little diversity of allowed gestures was also reported as a disadvantage. Cheng²⁶ proposed a testbed with participants to compare Myo, Kinect and a mouse/keyboard and conclude which one is the best interaction device. The winner was the couple mouse/keyboard for the simplicity of use. Regarding Myo, they concluded that the vibration that it produces is annoying and makes people nervous. Donato and Bullock²⁷, applied Myo to control audio interactively, including the sound level and the audio file. The authors enjoyed Myo's ease of use and highlighted its usefulness in handling mixed reality environments with audio. Finally, Sathiyarayanan *et al.*²⁸ are developing a robot for military purposes, controlled through Myo, which already has a recognized potential in this context. However, approaches where Myo is used to support people with disabilities are still scarce. To the best of our knowledge there is only one approach, proposed by Phelan *et al.*²⁹, in which a virtual kitchen was developed in a work that involved multiple interaction devices, such as: Kinect, Oculus Rift, headphones and Myo. The preliminary results seem to indicate that these devices may be relevant to amputees in the selection of prosthetic arms and related functionalities.

In the next section, a Myo-based HCI solution for upper limb amputees will be presented, namely the proposed system's architecture and an explanation of its components: gesture profiling and gesture matching.

4. Myo-based HCI solution proposal for upper limb amputees

The lack of technological accessibility is a real issue for upper limb amputees as they cannot easily interact with a computer or a similar device. Therefore, this section describes a myographic-based HCI solution that allows leg gestures as inputs and employs Myo as the interaction bridge between upper limb amputees and computers. To begin with, an exploratory experiment was made to check the viability of this proposal, mainly if the Myo armband could function correctly when used in a leg. This will be presented in the first subsection. Based upon encouraging results,

the second subsection presents a general architecture for the proposed solution, as well as the specification of the two main functional modules.

4.1. Leg gestures' characterization using Myo: a preliminary proof of concept

Myo operates with data acquired from two incorporated components: the inertial measurement unit (IMU) and the electromyographic (EMG) sensor (which is actually composed by eight individual sensors). While the former provides parameters such as speed, orientation and acceleration using a combination of inertial sensors (accelerometer, gyroscope, and magnetometer), the latter gives information related with the muscular electrical activity²³. Moreover, this device has a vibratory apparatus that provides haptic feedback at different intervals (small, medium and large), accordingly with the performed gestures.

Despite being designed to be worn on the arm, the authors were confident that Myo could also be used in the leg while maintaining its partial or full functionalities, based mainly in two assumptions:

- the legs are also human body limbs equipped with muscles that - just like arms - are liable of being measured regarding muscular activity and orientation;
- Myo is a full stack myographic device, equipped with sensors to acquire inertial and muscular activity data that has its own software development kit. This may enable the development of solutions for which it was not originally thought out.

Whilst the latter assumption is supported on documentation available in Myo's website¹, the former is based on the promising outcomes of an exploratory experiment carried out in which EMG and IMU data were acquired from three individuals that were using Myo in a leg (Fig. 2). The preliminary analysis made upon the resulting data revealed that those values presented a distinguishable and consistent variation among the experimented leg gestures.



Fig. 2. Exploratory experiment with Myo device placed in a person's leg. Similarly to what occurs in an arm, Myo bracelet is also capable of acquiring EMG and IMU data from a leg. It was noticed that several leg gestures were suitable to be profiled due to the differentiation and consistency of acquired data.

The process used to perform the preliminary analysis to the data obtained from the exploratory experiment was designed based on a set of observations and in some options. It will now be explained in detail, using as an example the two gestures depicted in Fig. 3.

¹ Myo's website available in <https://www.myo.com/>



Fig. 3. Two gestures - gesture A (first and second images) and gesture B (third and fourth images) - that were made with Myo placed in a person's leg, to better explain the leg gestures' characterization and comparison process.

To analyze the IMU data - the pitch, the roll and the yaw – a gesture was divided into five moments and at the end of each of those moments a reading was made. The acquired values were then converted to a range between 0 and 9 to simplify data visualization and its analysis. Although using the same gestures, the values between readings were not equal. After analyzing more data from gestures' readings, a pattern was found: in each gesture, the pitch, the roll and the yaw values usually have two states. Table 1 presents two readings (pitch, roll and yaw) for each gesture – a pre-acquired control reading and a sample reading - as well as an individual comparison between sequential gesture moments. The values obtained from the control gesture and from the sample gesture can vary but the moments' comparison patterns are almost always identical. For example, in gesture A, the roll value changed when comparing the first two moments in the control reading. In the sample reading that did not happen. However, regarding the yaw value when comparing the second and the third moment, the variation was the same in the two gesture readings. In gesture B, the yaw value varied when comparing the first two moments in the control reading but, in the sample reading, the roll value also varied. When comparing variation patterns between the same moments in different gesture readings (e.g. in gesture A, the comparison result between the first two moments of both readings), a gesture will be disregarded if there are differences in more than one of the parameters (pitch, roll or yaw).

Table 1. IMU data – pitch (P), roll (R) and yaw (Y) - for two readings of gestures A and B. Each gesture is divided into five moments for analysis purposes and the table also presents the comparison between the values of sequential moments.

Moments	Gestures and readings		Gesture A IMU readings						Gesture B IMU readings					
			Control			Sample			Control			Sample		
	P	R	Y	P	R	Y	P	R	Y	P	R	Y		
Moment 1	2	8	1	2	9	1	2	1	8	2	0	8		
Moment 2	2	9	1	2	9	1	2	1	7	2	1	7		
Moment 1 vs Moment 2	0	1	0	0	0	0	0	0	-1	0	1	-1		
Moment 3	2	9	0	2	9	0	3	3	6	3	3	6		
Moment 2 vs Moment 3	0	0	-1	0	0	-1	1	2	-1	1	2	-1		
Moment 4	2	9	0	2	9	0	4	3	6	4	3	6		
Moment 3 vs Moment 4	0	0	0	0	0	0	1	0	0	1	0	0		
Moment 5	2	9	0	2	9	0	4	3	6	4	3	6		
Moment 4 vs Moment 5	0	0	0	0	0	0	0	0	0	0	0	0		

In what regards EMG data, Myo outputs an identical muscular activity for identical gestures. Fig. 4 presents two graphics per gesture: the top row has two repetitions of gesture A and the bottom row has two repetitions of gesture B.

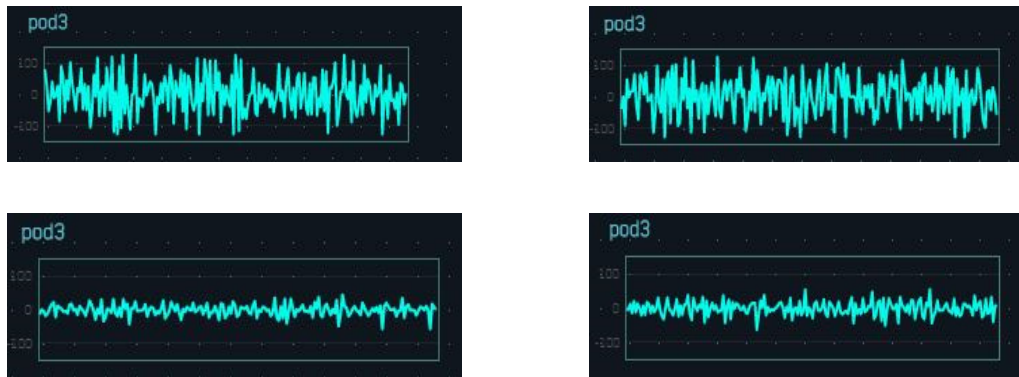


Fig. 4. Graphics showing the muscular activity of two repetitions of gestures A and B, obtained from Myo diagnostics page. The upper graphs are from gesture A, while the lower ones are from gesture B.

To analyze the EMG data – from the eight electromyographic sensors – a subset was created with the last hundred values acquired per sensor. This is because observations led to the conclusion that usually it is in the final moments of the gesture that there is more muscular activity. Then, the average value is calculated for each sensor and they are ordered from the highest to the lowest. After some analysis to gestures' EMG data, the conclusion was that they are distinguishable mainly through the highest values. Thus, the sensors position in the ranking and not their values are compared to assess if gestures are similar. The rule is that if the first three ordered sensors are the same in each gesture reading the remaining sensors positions are compared. If those are also the same or only one differs, gestures are considered similar. Otherwise gestures are deemed as different. Table 2 presents three readings (myographic) for each gesture – a pre-acquired control reading and two sample readings. As aforementioned, gestures are considered similar if their respective sensors' ranking coincides at least in six positions (one difference is allowed between readings, which implies that two positions are affected). For example, in gesture A, the sensors' ranking of the control and the first sample readings coincide in the first four positions. However, the last four positions do not match. Thus, the gesture made in the first sample reading is not considered similar with the control gesture. Regarding the second sample reading and in spite of the mismatch in the fifth (and consequently in the eighth) ranking position with the control reading, this gesture is considered similar, with only one different position. When comparing the rankings of both sample readings of gesture B with the control reading, they differ in the fifth (and consequently in the seventh) position. Thus, both samples gestures are considered analogous.

Table 2. This table presents EMG data (myographic) for three readings of gestures A and B. Each gesture has a control reading and two sample readings for comparison purposes. Every reading has a value calculated per sensor (the average value of the last hundred acquired values) and the respective position in the ordered ranking. Gestures are considered similar if their respective sensors' ranking coincides at least in six positions.

Sensors (Index)	Gesture A EMG readings		1 st Sample		2 nd Sample		Gesture B EMG readings		Control		1 st Sample		2 nd Sample	
	Control		1 st Sample		2 nd Sample		Control		1 st Sample		2 nd Sample			
	Value	Rank↓	Value	Rank↓	Value	Rank↓	Value	Rank↓	Value	Rank↓	Value	Rank↓	Value	Rank↓
0	4,36	3	3,29	3	4,52	3	1,95	3	1,32	3	1,32	3	1,32	3
1	5,85	2	5,02	2	6,49	2	3,98	2	2,42	2	2,42	2	2,42	2
2	41,48	4	30,81	4	43,41	4	12,84	4	11,03	4	11,03	4	11,03	4
3	48,27	1	33,38	1	55,62	1	27,96	1	22,64	1	22,64	1	22,64	1
4	11,26	0	11,35	5	20,1	5	5,82	0	6,81	5	6,81	5	6,81	5
5	4,08	6	3,54	0	5,89	6	1,58	7	1,34	7	1,34	7	1,34	7
6	4,2	7	3,1	6	5,11	7	1,34	5	1,24	0	1,24	0	1,24	0
7	4,19	5	3,01	7	5,07	0	1,6	6	1,34	6	1,34	6	1,34	6

Considering that the exploratory experiment's results have shown that Myo is capable of acquiring EMG and IMU data from a leg and that leg gestures can be profiled as they produce consistent and distinguishable signals, the authors propose an alternative interaction solution involving leg gestures' recognition using Myo, to promote the digital inclusion of those who live with partially or completely amputated upper limbs.

The next subsection will address an architecture and the specification of a HCI solution proposal for upper limb amputees, in which the Myo armband is used in a person's leg. Data acquired from Myo will be used to create a gestures profile for each person and to validate gestures, by comparing them to the ones saved in the individual profiles.

4.2. General architecture and specification

The underlying architecture to this HCI solution proposal for upper limb amputees, depicted in Fig. 5, has two main components: the HCI and the analysis and processing device. While the former is the Myo armband that is continuously transmitting EMG and IMU data acquired from a person, the latter consists in an analysis and processing device that deals with the received data sets, in two different modules: gesture profiling (GPM) and gesture matching (GMM). The GPM implements an initial training phase, necessary to acquire a person's gestures data and with it populate the gesture database, whereas the GMM regards to the process of comparing the acquired data sets with the recorded gestures' data: when they match up, a related action will be triggered (e.g. mouse right click, cursor navigation).

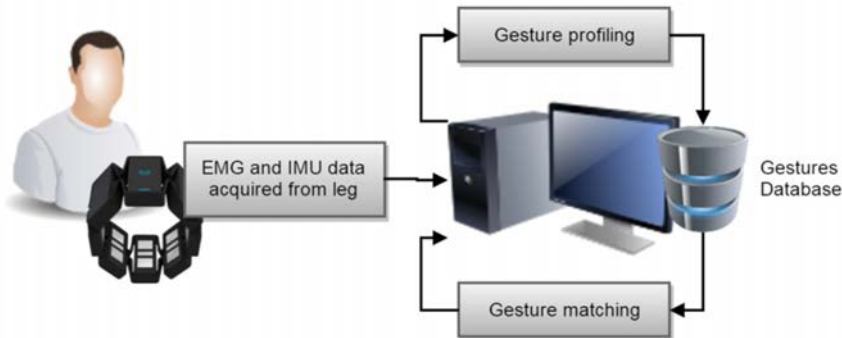


Fig. 5. General architecture for the proposed myographic-based interaction solution for upper limb amputees. The HCI – Myo armband – is represented in the figure's left side and is constantly transmitting EMG and IMU data to the analysis and processing device (figure's right side). The latter is capable of storing gestures profiles for predefined actions and when the solution is being used, tries matching up incoming data and recorded gestures to assist the person while performing tasks.

Fig. 6 presents a use case diagram specifying the interaction between an upper limb amputee and the proposed Myo-based solution, namely with the GPM and GMM modules. With the former, the person will establish a gestures profile, by recording some data sets related with the presently available predefined mouse actions - activate/deactivate, double-click, left click and right click - to the gestures database. This is typically done only the first time that the proposed solution is used. The latter module gathers the set of interactions which are related with the gestures that the person can input to perform an action, within a daily usage context.

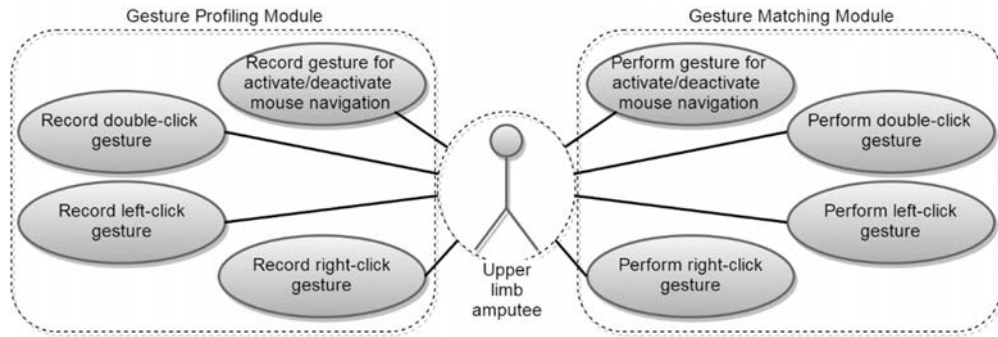


Fig. 6. Use case diagram depicting two strictly related functionality modules: the GPM involves training the Myo-based solution to obtain a person's gesture profile and the GMM gathers the daily actions that a person can perform, while interacting with the proposed solution.

To better explain both processes, Fig. 7 presents the GPM and GMM modules workflow diagrams. In what regards the capture of a single gesture for profiling purposes, depicted in Fig. 7 a), the process unfolds as following: initially, an action to associate a gesture is selected; then, the person must move the leg concordantly with the desired selected action (this has to occur a few times to ensure the robustness of the gesture which is being stored); finally, the gesture related with the selected action is saved to gesture database. When using the proposed Myo-based solution to interact with a computer in a daily context and for each provided gesture, the process - depicted in Fig. 7 b) – unfolds as follows: the EMG and IMU data representing the gesture is read; then, data is converted to a unified format for comparison purposes; converted data is then compared with each previously stored gesture; during the search, only a match triggers the related action.

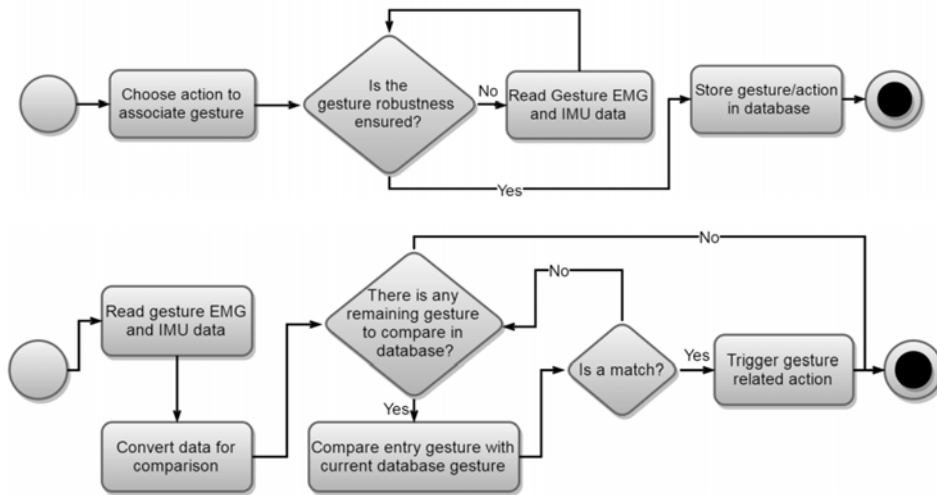


Fig. 7. Workflow diagrams depicting the proposed solution two main functionalities: a) depicts the gesture profiling process to record a user gesture and b) presents the process of comparing an entry gesture with the ones recorded in database, to try to find a match for control purposes, in a daily usage context.

This section has shown that Myo can be successfully used in a leg and that the respective gestures' signals are both consistent and distinguishable. Therefore, person-based gesture profiles can be created. A general architecture for the proposed Myo-based HCI solution was presented, as well as the specification of its two main functional modules and their respective workflow diagrams. In the next section, some conclusions will be drawn and the future work will be presented.

5. Conclusions and future work

Interaction plays a fundamental role as it sets bridges between humans and computers. However, people with disability are prevented to use computers by the ordinary means, due to physical or intellectual impairments, which may lead to this public's social exclusion¹. This paper presents a HCI solution proposal for upper limb amputees, supported on a myographic device named Myo that operates with data acquired from two incorporated components: the IMU and the EMG sensor.

Considering that Myo was design to be used in an arm, an exploratory experiment was carried out to assess the possibility of using Myo in a person's leg. In this experiment, patterns analysis for IMU data relied in the division of gestures into five moments and in a ranking approach for EMG readings. Some relaxation factors were also considered in both data types. The results have shown that:

- leg gestures can be profiled, as they produce consistent and distinguishable signals;
- Myo can also be used to interact with computers and similar devices while used in a person's leg.

As future work, the proposed myographic-based HCI solution will be implemented, considering the proposed architecture and specification. The solution will then be tested with upper limb amputees to optimize it and also to understand what are the advantages and disadvantages of interacting with it when comparing with other commonly used devices in the addressed disability.

References

1. K. Stendal. How do People with Disability Use and Experience Virtual Worlds and ICT: A Literature Review. *Journal of Virtual Worlds Research* 2012; 5:1-17.
2. A. Dix, J. Finlay, G. D. Abowd, R. Beale. *Human-Computer Interaction*. England: Pearson Education Limited; 2005.
3. Z. Ren, J. Meng, J. Yuan. Depth Camera Based Hand Gesture Recognition and its Applications in Human-Computer-Interaction. 8th International Conference on Information, Communications & Signal Processing 2011.
4. R. N. Valverde, F. G. Pereira, R. F. Vassallo. Reconhecimento de gestos dinâmicos usando modelos ocultos de Markov para interação homem máquina. *Simpósio Brasileiro de Automação Inteligente* 2011.
5. A. A. Stevens and K. E. Weaver. Functional characteristics of auditory cortex in the blind. *Behavioural Brain Research* 2009; 134– 138.
6. W. H. Organization. *International Classification of Functioning, Disability and Health*. Geneva: World Health Organization; 2001.
7. Bersch, R., Machado, R. *Atendimento educacional especializado*. Brasília: SEESP / SEED / MEC; 2007.
8. M. Monteiro, A. P. Matos, R. Coelho. A adaptação psicológica de mães cujos filhos apresentam Paralisia Cerebral. *Revista Portuguesa de Psicossomática* 2002; 149-178.
9. L. Pedro, J. L. P. Ribeiro, Implicações da situação profissional na qualidade de vida em indivíduos com esclerose múltipla. *Simpósio Nacional de Investigação em Psicologia* 2010; 1286-1294.
10. M. Figueiredo, V. Soares, R. C. Mota, M. A. João, S. Dias. Artrite reumatóide: um estudo sobre a importância na artrite reumatóide da depressão e do ajustamento psicossocial à doença. *Revista Portuguesa de Psicossomática* 2004; 13-25.
11. M. Rito. Doença de Parkinson: Instrumentos Avaliativos. *Revista Portuguesa de Fisioterapia* 2006; 27-45.
12. D. Murphy. *Fundamentals of amputation care and prosthetics*. New York: demosMedical; 2014.
13. U. Shrawankar and V. Thakare. Speech User Interface for Computer Based Education System. *International Conference on Signal and Image Processing* 2010; 148-152.
14. C. Sjöström. Designing Haptic Computer Interfaces for Blind People. *Signal Processing and its Applications* 2001; 68 – 71.
15. P. Majoranta e A. Bulling. *Eye Tracking and Eye-Based Human-Computer Interaction*. London: Springer-Verlag; 2014.
16. T. J. V. Guerreiro, J. A. P. Jorge. Controlo Miográfico de Dispositivos Móveis para Tetraplégicos. *Desenvolvimento de Software para melhoria de Acessibilidade e combate à Infoexclusão - DSAI* 2006.
17. R. P. Prado. Avaliação do uso de uma Interface Homem-Computador baseada em Eletromiografia em indivíduos com e sem alterações neuro-motoras de membros superiores. *Uberlândia: Universidade Federal de Uberlândia*; 2013.
18. R. K. d. Silva. *Interfaces naturais e o reconhecimento das línguas de sinais*. São Paulo: Universidade Católica de São Paulo; 2013.
19. Z. Zhang. Microsoft Kinect Sensor and Its Effect. *IEEE Computer Society* 2012; 4-10.
20. L. E. Potter, J. Araullo, L. Carter. The Leap Motion controller: A view on sign language. *25th Australian Computer-Human Interaction Conference: Augmentation, Application, Innovation, Collaboration* 2013.
21. SoftKinetic. *Human Tracking Library (DEPTHSENSE® HTLIB)*. 30-01-2016. [Online]. Available: www.softkinetic.com/Products/HTLib/HTLib3.
22. T. Labs. Discover Myo. 09 09 2015. [Online]. Available: <https://www.myo.com/>.

23. M. Sathiyarayanan, T. Mulling. Map Navigation Using Hand Gesture Recognition: A Case Study Using MYO Connector on Apple Maps. *Procedia Computer Science* 2015; 50-57.
24. T. Labs. Welcome to Myo Support. 10 09 2015. [Online]. Available: <https://support.getmyo.com/hc/en-us>.
25. K. Nymoen, M. R. Haugen, R. A. Jensenius. MuMYO — Evaluating and Exploring the MYO Armband for Musical Interaction. NIME 2015; 3-6.
26. Z. Cheng. Gesture Control in a Virtual Environment. Australia: Australian National University; 2015.
27. B. D. Donato, J. Bullock. GSPAT: Live sound spatialisation using gestural control. International Conference on Auditory Display 2015; 10-12.
28. M. Sathiyarayanan, T. Mulling, B. Nazir. Controlling a Robot Using a Wearable Device (MYO). *International Journal of Engineering Development and Research* 2015; 1-6.
29. I. Phelan, M. Arden, C. Garcia, C. Roast. Exploring Virtual Reality and Prosthetic Training. 2015.