EMG-based human-machine interface to control multimedia

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***Abstract*—The EMG signals acquired from muscles are used in high-tech fields such as augmented reality, biomedical, gaming, 3D animations and human-machine interfaces. The latter are used especialy for helping people with reduced mobility or having special needs to control machines. The purpose of this paper is to realise a novel, flexible and efficient EMG-based system in order to control a multimedia systems. A comparison study is also given to show the utility of the application, then numerous evaluations were provided to validate our apporoach. A real implementation of the application is realised, and validated with many tests. Finaly we present our experimental results and the future works**

***Index Terms*—EMG, muscle, signal processing, media player, control interface**

I. Introduction

The EMG signal provides an intelligent and natural way of a human machine interaction, which can be a good solution to replace conventional controls interfaces and allows some categories of users the opportunity to exploit the new technologies. In augmented reality, by implanting electrodes in different ways in the human body, especialy in his feets, legs, arms, hands, and his face we can create a virtual human user, witch has a total control of his body members. We can find the EMG technology in the Control Command field. In nuclear power plants or in the big factories, for some critical and dangerous tasks emploies use EMG-based robots, witch allows more security and safety. The EMG technology is used also in biomedical field, gaming field, 3D animations and human-machine interfaces field.

Amputation and deformity have been dealt with, one way or another, throughout the ages. More than one million individuals in the United States today are living with limb amputations [1], in which there are thousands patients with an upper limb amputation. According to [2] approximately 8% of physical disables, or 2.26 million people, live with limb amputations in China alone. Natural disasters and accidents have been making this number increase. For this reason, over the years many searchers have focused on the creation of artificial limbs and the realisation of Human Machine interfaces controled by the EMG signal, which can be one of the most interesting solutions. The use of EMG is not limited, which is explained by the diversity of the applications that we can be found today.

Several researches and applications have treated the EMG signals. In fact, numerous studies have been made on classifications and treatments of it. for instance, on facial expressions recognition by analyzing physiological signals, on detection and identification of the uterine EMG signal for prediction of premature child-birth. Our study is focused on the EMG signals generated by a human hand or arm. We aim to develop an application that controls a set of media, using the EMG signal with arm force. The electrical potential generated during a contraction of an arm muscles permits to start a video or switch between a set of media. Our proposed system has been developed in the purpose of creating an EMG-based remote control that allows more simplicity to use than the classical methods, especially for helping people with reduced mobility.

The rest of this paper is organized as follows. Section II reviews relevant related work and different existing approaches for exploiting the EMG signals. Section III presents our approach for using the EMG signals to take control over a multimedia application, and we present some tests that we have done and their results . Section V concludes this paper and presents some perspectives for our futur work.

II. Related work

Numerous studies have been made in the area of EMG. Authors in [3] showed that the EMG allows to measure the facial electrical activity of muscles via electrodes placed on the face, this measure can be used for expressions recognition. From this facial expressions we can distinguish a stress which causes an increase muscular activity and many others expressions as negative valence, lack of motivation,.etc.

Its approach consists to realise an immersive simulation platform for job interviews, which is based on a set of sensors which are used to acquire physiological signals (EMG, ECG,.etc). These signals are processed as follows (extraction, characteristics, classification and performance evaluation of classifiers). The purpose of this platform is to improve the candidate's behavioral skills and training him to manage his emotional state by using the data that is gathered from him.

The system can give a misinterpretation of the user's face, but in general it remains a good work that brings a new solution that did not exist before, which can be very handy if some improvements were added.

The EMG signal can enable better monitoring of the contraction's evolution during the pregnancy [4] .

Indeed, the precocious detection of premature birth is the key of prevention. The treatment method of EMG uterine for detecting and identifying the pertinent events is based on the wavelet packets. The author propose two approaches for an

EMG uterine decomposition, discrete wavelet decomposition which consists to decompose the EMG signal according to the scale levels. this scale interprets any change in frequency or energy signal. And the second approach is the wavelet packet decomposition which is based on the construction of sub-basic functions organized into packets. These approachs permit to choose the most pertinent packages for the good detection and classification of an EMG uterine. Furthermore, we can use other types of frequency wavelet that are more selective.

Several methods in [5] are successively applied on the EMG signals so it can be interpreted. The important step is to extract the most discriminative features. Then, various types of classifiers may be used, each one of them presents advantages and disadvantages. None of them for the moment won unanimously. The objective of these classifiers is to choose a reliable and fast learning mechanism, a way to be adapted to control a hand prosthesis.

These classifiers are poorly adapted to the changes of the signals occurring from different operators over the time.

Author in [6] treat the problem of EMG signal decomposition based on the observation from a single sensor. According to it and to [7], the decomposition consists in the restitution of pulse train for each motor unit corresponding, and enables the subsequent analysis of muscle motor units proprieties, providing an interpretation of the neural roles in the muscle. The decomposition process is performed in two steps: pretreatment for segmenting the EMG signal and provide an approximation of the shapes of elementary waves, followed by a "Bayesian decomposition" that use the stochastic simulation approach, (MCMC). The strength of this solution is that, unlike existing methods, no human manipulation is involved in this process, both steps are fully automatic. This work is bringing a new solution, however it lacks a technical implementation in addition to simulation that has been achieved.

Authors in [8] propose a new method that allow users to control an anthropomorphic robot arm in a 3D space, by developing an interface between the user and the robot arm which is controlled by EMG signals. The efficacy of this proposition is that the experiments are done in real time, including random arm motions with variable hand speed profiles, and those arm motions are not affected by EMG changes with respect to time, and that is done by using a switching model in such a way that it compensated for the EMG changes. This solution is very convenient but the only problem is that the use of robots is not within the reach of everyone and it can be very expensive.

Studies in [9] describes a new hand gesture recognition system based on both multi-channel surface EMG sensors and 3D ACC (accelerometer) to realize a flexible interaction between human and computers. The set of defined hand gestures include both finger actions and circular hand movements of various orientations. To evaluate their system they implemented an application that allow to control Virtual Rubik's Cube game. This work is very interesting because it combines two sensing techniques for hand gestures recognition, thus, precision and efficiency are enhanced. However, this application is not that practical for people whom cannot move their hands in a proper way (circular movements of various orientations).

Authors in [10] propose an interface of "control command" between the prosthetic hand and the human. The human communicates with the prosthetic by sending commands "to keep a hand open, to keep pincer position, keep a encompassing entry position,..etc. On the other hand, the prosthetic hand communicates with the human by displaying messages that are:

Send error messages (when the system does not know the signal value). Raise an alarm in case of fatigue. View the status of the battery.

This solution allows creation of a simple and useful prosthetic hand which is easy to use. But the main problems that we can encounter, is when error messages are displayed on the screen in the case of a co-contraction (contraction of two muscles in the same time), when the prosthetic receives an unknown signal, and when the amplitude of the signal does not indicate a weak nor a strong contraction (between the two).

In addition this solution is not optimal nor flexible because when we want to move from an encompassing state to a pinching state , we have to go through an open state.

Finally, this work has not been implemented yet, so we cannot know what technical problems that can be encountered.

In this paper, we aim to develop an application that control set of medias by using EMG signal with hand force. The electrical potential generated during a contraction of muscles arm permit to switch between this set of medias. Our proposed system has developed in the purpose of helping person with reduced mobility.

III. Proposed Approach

The control strategies of the application use three electrodes placed on the skin surface overlying the muscles of the arm in order to gather the EMG signals. In this section we will explain the signal processing in details and then the implementation of the system.

Herein, we present the analysis of the EMG data that we have achieved on the data collected from the arm muscle by three surface electrodes placed on the skin.

The EMG signals acquired from muscles require advanced methods for processing which are as follows (loading, rectification, filter, linear envelope and fourier transform) showed in figure 1. The purpose of this treatment is to turn the signals into a usable form for registration or correlation purposes.

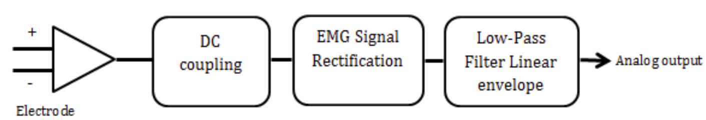


Fig. 1. EMG signal processing diagram

1) Loading the EMG data: This step is a presentation of the data without processing, except an amplification of the signal that can be added by the electrode. The raw signal is presented in figure 2 .

2) Rectification the EMG signal: A full rectification generates the absolute value of the EMG signals, it can be also called an average value. Two phases can be distinguished to obtain the average value, as follows: eliminating the offset signal by removing the dc-offset and calculating the absolute value. the results are showed in figure 3.

3) Filter and Linear envelope of the EMG signal : Filtering the signal serves to eliminate the unwanted noise, There are three types of noise in a the EMG signal,

Bio-electrical noise: that is produced by biological functions, heartbeat, breathing and it can be minimized with good electrodes placement.

Equipment noise: it is a noise due to the wires movement, electrodes, skin and amplifiers. the wires noise have a low frequency (10-20 Hz), so filtering at 20 Hz eliminates them. The amplifier's noise is of higher frequencies and it can be found in the upper part of the frequency spectrum of the EMG signal.

External noise: All electrical and electromagnetic interference, it can be minimized with a good grounding (GND)

Filters reduce the amplitude of the signal at a given frequency (cutoff frequency), we have used a low pass filter for our treatment of the EMG signal. The cutoff low-pass frequency is often set at around 250 Hz for surface electrode. The linear envelope is the result of a full rectification and low-pass filtering at sampling frequency 2000 Hz, as we can see in figure 4.

4) Fourier Transform (FFT) of the EMG signals: The Total Power Spectrum can be calculated by two frequency parameters: Mean Frequency of the FFT as the mathematical mean of the spectrum curve, Total Power as a the integral under the spectrum curve and Median Frequency of the FFT as the parameter that divides the Total Power area into two equal parts [11] presented in figure 5.

Finally the maximum value of the Total Power Spectrum curve can be used to describe frequency characteristics. Within applied EMG-frequency analysis the most important parameters are the mean and the median frequency and their time domain changes in sustained contractions, which is often employed for analysing muscle fatigue.

The user of the application should place three electrodes

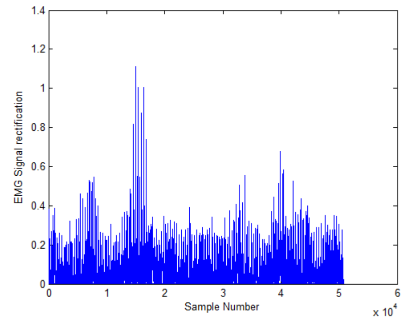


Fig. 3. the EMG signal Rectification

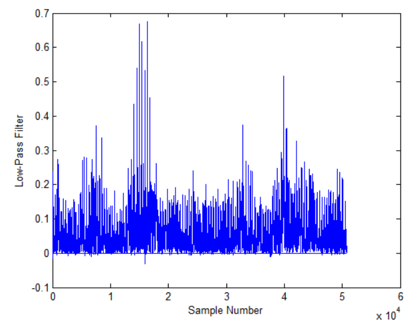


Fig. 4. Linear envelope

in his arm, which consists to acquire and amplifie the EMG signal gathered from muscles. The signal is processed and filtered, then during a contraction, we can find different values depending to the strength of the contraction. First to show the contractions to the user we have used a "LED", which turns "ON" in case of a contraction, and "OFF" otherwise.

Then we developed a basic mediaplayer, controlled by the same principle of the LED with just one command allowing to star a media. In other words when the user make a contraction, there is signal sent into the application and get started the media. Figure 7 show an exemple of use of the application.

Figure 6 shows the architecture of our system:

So here the user launches the command to start the media, we can see also the different components of the interface :

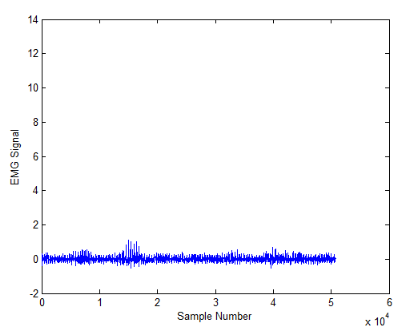


Fig. 2. EMG Data

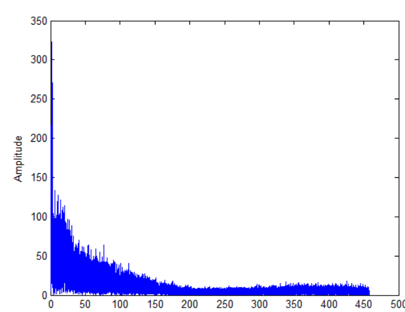


Fig. 5. Power Spectrum

a progress bar and an LCDNumber for displaying the signal strength of the user, a button to choose the media, and the media viewer.

To enhance the application and to make it more flexibale and useful, we have added a lot of options. So first, we have done studies on some existing methods allowing an intuitive detection of the location of electrodes and their adaptation with the arm of the user. This step is very important, because The shape and the amplitude of the EMG signal are influenced by the location of the electrodes. Therefore the amplitude of the recorded signal decreases exponentially with respect to the distance between the electrodes and the source of electrical activity. This required setting up a correction method to simplify the eletrodes placement, in our case we opted for clustering algorithmes (K-means).

The users (man, woman and child) do not have the same EMG signals strength, in addition it may be that the same user does not have the same force when he is fit and when he is tired. Which requires a learning phase that permits the adaptation of the strength threshold with the proper user. So the user -before commanding the application- has to do some tests in order to know to which cluster he belongs. In this phase we also used k-means for the classifiction of the individual. And, once the category of the user is determined, the system adapts the threshold according to the user.

Then, several fonctionalities were added, like stop media, change it, come back to the previous one,.etc, while, at the same time, keeping the user-friendly side of the system. Thus,

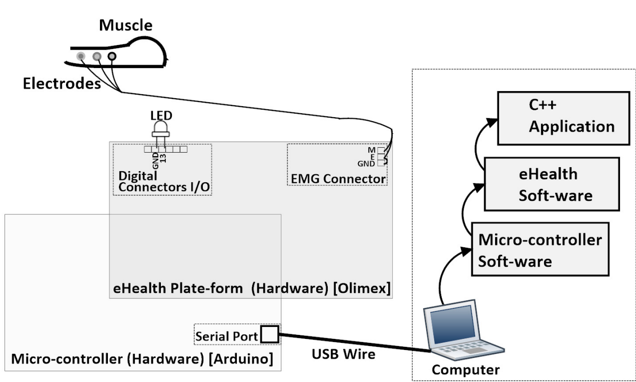
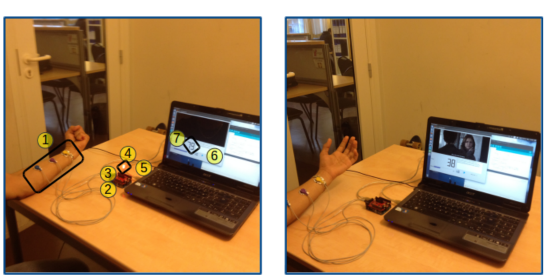


Fig. 6. System architecture



1- Electrodes, 2- Microcontroller, 3- eHealth platform, 4- LED, 5- Serial port, 6- Application 7- Force.

Fig. 7. Example of use case

creating other commands was realised according to three parameters : "Force", "Timing" and "Contraction frequency". So in our application we need to create four commands, C1 : to start the first media or to get the following ones, C2 : to return to the previous media, C3: to pause the media or to continue, C4 : to stop the media.

		Timing			
		<T	>T	<T	>T
Force	W	F=1 C1	F=1 C3		
	S		F=1 C4		
	W	F=2 C2	F=2 C2	F=1 + F=1 C2	F=1 + F=1 C2
	S	F=2 C2	F=2 C2		

TABLE I
COMMANDS CLASSIFICATION

Table I shows the combination of different parameters allowing the creation of new commands. Where the Force can take two values "Strong" and "Weak", the Timing can take two intervales "[0,T[" and "[T,+inf[" where T is the time (in seconds) of maintaining the contraction, and F1, F2 are respectively Frequency = 1 and Frequency = 2. We have defined "t" the maximum period between two frequencies to make the difference between "one command with two frequencies" and between "two different commands", "t" hase been defined based on many tests (detailed on **??**). With this combination of parameters, we have created four commands (six fonctionalities) without any ambiguity. So we can interpret the table as follows : C1(Start|Next) = W + <T, C2(Previous) = (2W|2S|S+W)+(<T|T>) which "|" means "or", C3(Pause|Continue) = W + >T, Finally C4(Stop) = S + >T.

Then, for a more simplicity, especially for people who cannot move their fingers, we can use a dynamic media list, by creating a file or a database containing links (URLs) downloaded and updated automatically from the Internet.

Finally, we made our tests by using wired electrodes that will be replaced later by wireless electrodes, which gives more flexibility, light weight and robustness to our system.

IV. Experimental researches

In our application, we have used 3 modules: Gui for building the graphical interface, Core module which contains core non-GUI functionalities and finaly, phonon module for multimedia applications. To understand the application's architecture, the following class diagram (Figure 8) models the multimedia application structure. The "main" class is associated with the "QApplication" and the "control" class which inherits from the "QObject" and is associated with the "QSerialPort" and the "Thread" classes. The "Thread" class inherits from the "QWidget" class and is associated with the "QThread" and the "scene" classes. Finaly, the "scene" class inherits from the "Ui::scene" and the "QMainWindow" classes and is associated with the "phonon" and the "multimedia" classes .

COOOMMMMENT on a choisi le seuil

EEEEEVVVVValuation

IIIIILLLLL va faloir que je parle ddu choix du timing et du frÃl’quence. et comment j’ai mis le >T et <T et le "t" et en fonction de quoi.

+RÃl’fÃl’rence Ãă corrigÃl’.

V. Conclusion and futur works

In this paper, we proposed an approach to control a media player by using the EMG signals. Before exploiting the EMG signals, it has to go through some specific processing steps in order to have better results. The approach is designed to provide a control interface destined especially for people with reduced mobility. Thus we have done a real implementation of the application. To create commands, we have combinated different parameters in order to get a performed interface without any ambiguity on controling it. Our experimental results show that this proposed approach realises an intuitive and user-friendly human machine interface, and it is able to achieve a good performance. Our future work will focus on the adaptation of this remote on handling multiple applications at once, such as controlling a TV, turn ON and OFF the light of the room, start the robotic vacuum cleaner,.etc, while, at the same time, keeping the flexibility of the system.

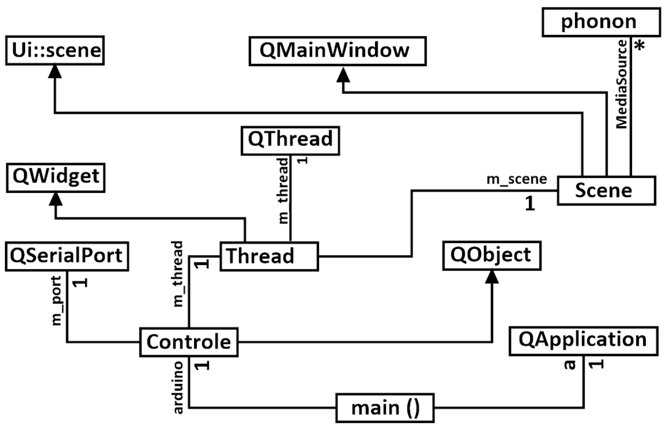


Fig. 8. class diagram of the application

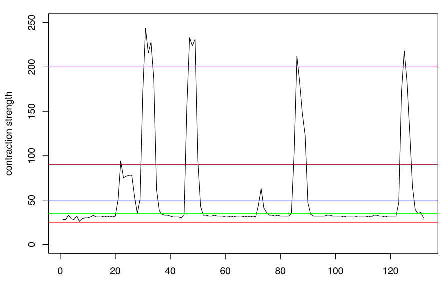


Fig. 9. class diagram of the application

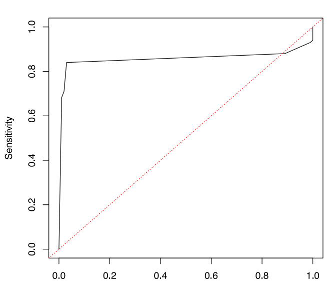


Fig. 10. class diagram of the application

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