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Robust hand gesture recognition with a double channel surface EMG wearable armband and SVM classifier

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ABSTRACT

Integration of surface EMG sensors as an input source for Human Machine Interfaces (HMIs) is getting an increasing attention due to their application in wearable devices such as armbands. For a wearable device, comfort and lightness are important factors. Therefore, in this article we focus on a minimalistic approach, in which we try to classify four gestures with only 2 EMG channels installed on the flexor and extensor muscles of the forearm. We adopted a two-channel EMG system, together with a high dimensional feature-space and a support vector machine (SVM) as a classifier. In addition, tolerance of the system for rejection of unsolicited gestures during the body movement was evaluated, and the two methods were implemented to ensure this; one based on an SVM threshold and another one based on the addition of a locking gesture. The resulting system is able to recognize up to 5 gestures (hand closing, hand opening, wrist flexion, wrist extension and double wrist flexion), presenting a classification accuracy of between 95% and 100% for a trained user and robustness against different body movements, guaranteed with the locking feature. We showed that misclassification of other gestures as the unlocking never happened for expert users.

1. Introduction

Surface EMGs have been mostly used for control of prosthetic hands. Full control of a highly articulated hands still requires a high number of EMG sensors, raising significantly the cost and complexity of the system. It is a common configuration to utilize four EMG channels, as adopted in [1] and [2], in order to be able to detect wrist and 4-fingers flexions and extensions (Fig. 1); other authors, like Yang [3] and Bugmann [4], used 6 bipolar electrodes for recognizing up to 19 and 15 hand movement respectively and controlling a highly dexterous hand. These control systems require a high number of control inputs. Some other studies reported application of eight [5] or ten [6] bipolar electrodes positioned on the forearm.

Other examples of utilizing surface EMG sensors include finger joint angle estimation using a 8 channel EMG system [7] and hand gesture recognition using a 6 channel EMG armband [8]. Also, in a recent study authors discussed the selection of best subsets of EMG electrode pairs for classification of hand movements when performing 5 hand postures at 9 different arm positions [9].

Surface EMG sensors that were previously exploited only for prosthetic devices, were considered as an important source of input for general purpose Human Machine Interfaces (HMIs) for wearable devices. For such devices, it is always interesting to received as many inputs as possible, and classify as many gestures as possible, to enrich the human control over the machine. BioSLeeve [10] is an example of a wearable device that implements 16 electrodes.

Recently, a gesture recognition armband, the Myo armband was commercialized [11]. As can be seen in Fig. 2, this armband is able to detect five gestures, which are open, wave out, wave in, fist and pinch. Myo armband embeds eight EMG channels, and is designed as a wearable armband. Yet, Myo is relatively bulky as a wearable device.

The purpose of this article is then to explore a minimalistic approach in order to achieve hand gestures. Therefore, we explore recognition of four hand gestures (open, close, wave in, wave out) with only two EMG channels.

While, the “Open” and “Close” gestures, or more generally two gestures recognition with a single EMG channel have been already explored [12,13], adding the “wave in” and “wave out” gesture provides new possibilities for the user. The goals is then to build a real-time classification algorithm for recognizing these 4 gestures

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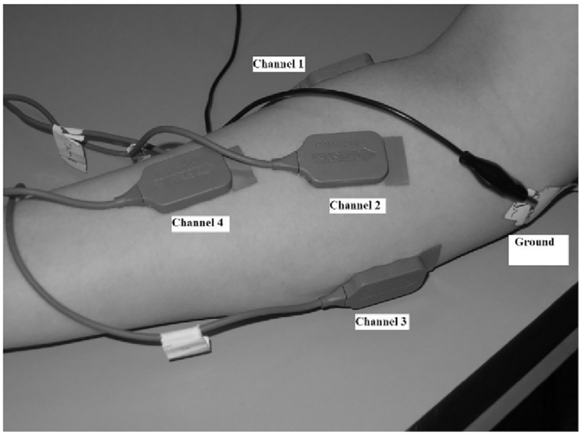
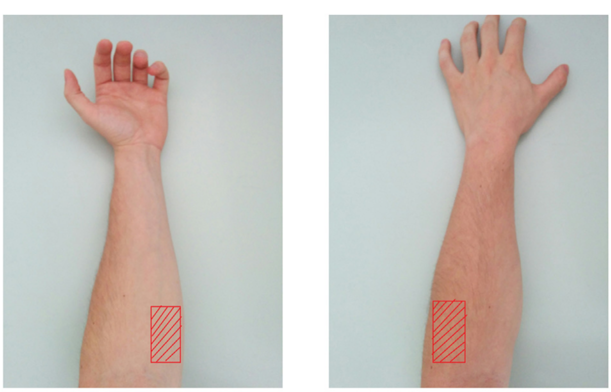


Fig. 1. 4 bipolar electrodes placement on the forearm.

Fig. 2. The Myoarmband integrates 8 EMG channels and an IMU unit and can detect up to 5 gestures.



(a) Channel 1 *(b) Channel 2*

Fig. 3. Indicative zones for electrodes positioning.

and measuring the success rate in real-time classification. Therefore the following constraints are fixed:

(1) The number of inputs is reduced to two, that is, the 4 necessary gestures must be recognized by using only two signals.
(2) The classifier must achieve good gestures recognition percentage, e.g. over 90%.
(3) The processing time for calibration must not exceed 30 s; moreover, the algorithm must be trainable with a small training set, asking so the user to perform a minimum number of gestures for the calibration.

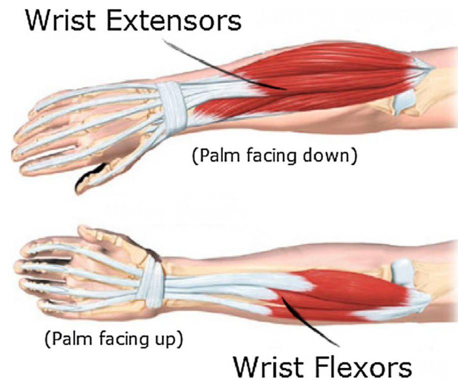


Fig. 4. The forearm anatomy, Wrist Flexor and Extensor muscles.

(4) The system response to a gesture performing must not exceed 300 ms for user comfort.
(5) The classifier should allow to be used without re-training it in every session; even when the algorithm is not re-calibrated.
(6) The system must provide robustness against other limb movements, that is, the disturbances coming from these motions must not be classified as one of the three gestures, letting the user move freely when wearing the EMG device.

In the following chapters, we describe the system design, the features of the signal that were extracted and the classifier which was selected and implemented. We then show the result of the system implementation for 7 subjects (four males and three females) that tested the system. Subjects were all healthy, with an average age of 25.6 years ($SD = 5.7$), with different levels of previous acquaintance with the system. The last constraint (tolerance to disturbances) actually found to be the most challenging for some of the beginner users, which enforced integration of a fifth gesture, as an option, for locking the system. Tests were repeated for beginner subjects and the results are presented.

2. EMG system design and implementation

As described before, the goal of the design is to recognize hand gestures with satisfying reliability, for which we set at 90% the lower bound of correctly classified gestures. Moreover, we decided to use dry electrodes instead of gelled ones, to increase the comfort and durability of the system. Therefore we used stainless steel electrodes. The positioning of the two channels should follow the scheme shown in Fig. 3; however, we experienced during the test sessions that the optimal positioning could be considerably different for every subject, hence, the setting depicted in Fig. 3 should only serve as a starting point. Fig. 4 shows the forearm anatomy of the wrist flexor and extensor.

Each channel was then composed by 3 electrodes put in a row along the monitored muscle (which traduces in the same direction of the forearm), two of them providing the differential signal, and the middle one working as a common ground (the two resulting grounds from the 2 channels were connected together).

2.1. Hardware, pre-processing and acquisition

Before being acquired by the micro-controller, the signal is filtered and amplified. More precisely, the differential signal first passes through an instrumentation amplifier with high CMRR and unitary gain to eliminate common noise sources, such as the 50 Hz line noise; after that is filtered by a second order band-pass Sallen-Key filter with cut frequencies at 10 Hz and 500 Hz and amplified by a gain of 65 dB (1800). These operations were implemented in