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Performance of Forearm FMG and sEMG for Estimating Elbow, Forearm and Wrist Positions

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Abstract

The ability to track upper extremity movement during activity of daily living has the potential to facilitate the recovery of individuals with neurological or physical injuries. Hence, the use of Surface Electromyography (sEMG) signals to predict upper extremity movement is an area of interest in the research community. A less established technique, Force Myography (FMG), which uses force sensors to detect forearm muscle contraction patterns, is also able to detect some movements of the arm. This paper investigates the comparative performance of sEMG and FMG when predicting wrist, forearm and elbow positions using signals extracted from the forearm only. Support Vector Machine (SVM) and Linear Discriminant Analysis (LDA) classifiers were used to evaluate the prediction performance of both FMG and sEMG data. Ten healthy volunteers participated in this study. Under a cross validation across a repetition evaluation scheme, the SVM classifier obtained averaged accuracies of 84.3%, 82.4% and 71.0%, respectively, for predicting elbow, forearm and wrist positions using FMG; while sEMG yielded 75.4%, 83.4% and 92.4% accuracies for predicting the same respective positions. The accuracies obtained using SVM are slightly, but statistical significantly, higher than the ones obtained using LDA. However, the trends on the classification performances between FMG and sEMG are consistent. These results also indicate that the forearm FMG pattern is highly influenced by the change of elbow position, while the forearm sEMG is less subjected to the change. Overall, both forearm FMG and sEMG techniques provide abundant information that can be utilized for tracking the upper extremity movements.

Keywords: Surface Electromyography (sEMG), Force Myography (FMG), classification, limb movement, activity monitoring, upper extremity

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1 Introduction

Studies show that being able to monitor the amount of limb movement performed by an individual with neurological or physical injuries outside a clinic can facilitate recovery[1,2]. For lower extremity rehabilitation, the step count of a pedometer provides an objective feedback on the amount of lower limb exercise that the users perform during their daily routines[3–6]. This information helps therapists monitor the rehabilitation progress and encourages individuals to reach their exercise target. For upper extremity rehabilitation, an accelerometer can be used for measuring the gross amount of arm movement in research settings[7,8]. However, this gross measurement only captures the intensity and does not count and distinguish the types of movements, *e.g.*, extension and flexion of the elbow or wrist[7]. Knowing the type of movement that the individual performs allows therapists to better assess the rehabilitation progress of their clients[8].

In the past two decades, researchers have investigated the use of Surface Electromyography (sEMG) signals to decipher upper extremity activities[9]. sEMG is a non-invasive technique for registering electrical activities generated by the motor units of the skeletal muscles[10]. Using machine learning techniques, sEMG extracted from the forearm can be used to monitor gestures of the hand and positions of the wrist and forearm joints[11]. sEMG electrodes placed on the forearm also record information associated with elbow joint position[12]. The ability to detect multiple joint positions from forearm sEMG alone is an added convenience for

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the end user because sensors are not needed to be placed on different locations of the limb for monitoring upper extremity activities.

A less established technique, Force Myography (FMG), can also detect upper extremity movements[13,14]. The term FMG[15], refers to a technique which uses force sensors surrounding a limb in order to register the volumetric changes of the underlying musculotendinous complex during muscle contraction. FMG can be considered as a subcategory of mechanomyography[16,17], which only registers lower frequency information (less than 10 Hz) that relates to the physical movement of surface skeletal muscles. The technique described by FMG is also referred to as topographic force mapping[18], residual kinetic imaging[19] or muscle pressure distribution mapping[14]. Similar to the forearm sEMG, studies show FMG signals extracted from the forearm are able to detect some static hand gestures[13,14], some positions of the wrist[13] and some elbow related movements[20–22].

The literature shows that both FMG and sEMG signals extracted from the forearm have the potential to predict movements of the elbow, forearm, and wrist which can be utilized for tracking upper extremity activities for rehabilitation applications. This paper investigates the potential difference in performance between sEMG and FMG when predicting wrist, forearm and elbow positions for a total of 45 defined set of arm postures. An experiment designed to collect forearm FMG and sEMG for limb position classification is presented in this paper.

2 Methods

An experiment was designed to investigate the capability of using FMG and sEMG separately to detect the positions of elbow, forearm and wrist. The experiment consisted of two parts: data collection and data processing as described in the following subsections.

2.1 Data collection

2.1.1 Hardware for signal acquisition

Fig. 1 shows a customized strap for capturing FMG signals from the forearm using Force Sensing Resistors (FSR402 from Interlink Electronics)[23]. The strap has a length of 28 cm and was designed to be worn on the largest part of the forearm. The strap was made of flexible foam for user comfort. Eight circular FSRs were embedded in the strap to sense the pressure applied by the forearm muscles. Each FSR was equally spaced so its position could easily be adjusted to fit different forearm sizes. The FSR signals were extracted using a voltage divider circuit. Each FSR had two terminals, one was connected to a constant voltage supply (+ 5 V) and the other was connected to a fixed resistor with a resistance of 22 kOhm. The junction between FSR and the resistor forms the signal output terminal. The signals were digitized by using a Data Acquisition Device (DAQ) from National Instrument (USB-6210) and sent to a computer via a Universal Serial Bus (USB) port.

Fig. 1 FSR strap prototype.

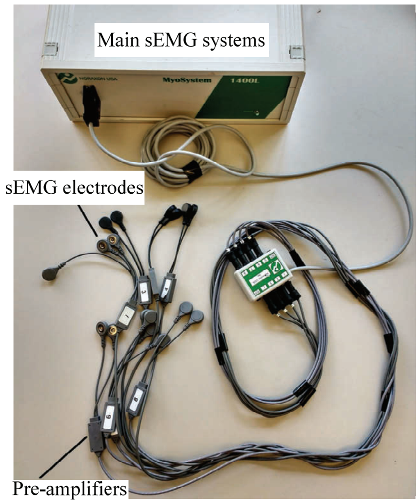

Fig. 2 sEMG signal acquisition systems.

To capture high quality sEMG signals from the forearm, a medical grade acquisition system from Noraxon (Myosystem 1400L) was used (see Fig. 2). This system has 8 bipolar sEMG active electrodes, and each electrode has a built-in amplifier with a gain of 500. After the pre-amplification, the signals of the 8 electrodes were fed to the main amplifier unit for further signal amplification and filtering. Finally, the filtered signals were digitized by the same DAQ used for the FMG strap.

2.1.2 Software for signal acquisition

A Graphical User Interface (GUI) was developed in LabVIEW from National Instruments for the FMG and sEMG data collection. This GUI showed the real-time FMG or sEMG signals, and had a panel on the computer