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Hand/arm gesture segmentation by motion using IMU and EMG sensing

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Abstract

Gesture recognition is more reliable with a proper motion segmentation process. In this context we can distinguish if gesture patterns are static or dynamic. This study proposes a gesture segmentation method to distinguish dynamic from static gestures, using (Inertial Measurement Units) IMU and Electromyography (EMG) sensors. The performance of the sensors, individually as well as their combination, was evaluated by different users. It was concluded that when considering gestures which only contain arm movement, the lowest error obtained was by the IMU. However, as expected, when considering gestures which have only hand motion, the combination of the 2 sensors achieved the best performance. Results of the sensor fusion modality varied greatly depending on user. The application of different filtering method to the EMG data as a solution to the limb position resulted in a significative reduction of the error.

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Keywords: Gestures; Segmentation; Motion; IMU; EMG

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1. Introduction

One of the most intuitive methods for Human Machine Interaction (HMI) is gesture spotting: robots performing defined movements based on gestures which are performed by humans. These movements are generally executed in sequence in order to perform complex tasks. Multiple solutions have been presented for gesture spotting, such as gesture detection through body-worn sensors or using computer vision or even hybrid solutions.

Methodologies for gesture segmentation have been studied such as [1], that has tackled this problem using a data glove to detect hand and arm gestures performed by the user. In [2], the authors propose to use IMU sensors on a lower limb exoskeleton. According to [3], IMUs have some associated benefits in comparison to other sensors. The main advantages mentioned are: there is no inherent latency associated with this sensing technology; and all delays are due to data transmission and processing. Other major issue about IMU is drift [4].

Electromyography (EMG) is a method for recording and analyzing electric signals resulting from neuromuscular activity, also known as electromyograms. Using multi-channel EMG recordings it is possible to identify the movement being performed [5]. Classification performance of EMG features for hand and arm movements was studied using data from 15 EMG sensors placed on the forearm [6]. Contractions performed at different force levels may be very different from one gesture sample to another and therefore present a challenge to a pattern classifier [7]. The variation of limb position degrades myoelectric pattern recognition performance [8]. In [9] it was studied the effect of arm movements in EMG pattern recognition, including both static and dynamic arm motions. It was concluded that dynamic change of arm position had seriously adverse impact on sEMG pattern recognition. In [10] the authors claim that the hand gesture data is not as useful as it may appear. First, given that the hand gesture is calculated from the EMG data measured on the skin of the forearm, which is a side effect of the muscle movement, there is a possibility that the calculated gesture may not loyally indicate the actual gesture of the hand. Second, when exterior forces are applied to the muscles or there is some other interference with the EMG readings such as tight clothes, the accuracy of the measurement can be vastly degraded, to the point where the gesture data may not be usable at all. According to [11], multimodal sensor fusion combines information from different sensor modalities to overcome the shortcomings of each sensor. An example of this application can be seen in [12], where a system for recognizing hand and finger gestures is presented, and the achieved conclusion is that the system benefits from the combination of both sensor modalities. An example of this application can also be seen in [13], where an accelerometer is used in conjunction with EMG in order to improve classification results of arm movements.

This manuscript aims to evaluate the performance of IMU and EMG sensors in regards to gesture segmentation, aiming to distinguish dynamic motions from static postures.

2. Sliding window

In order to study both arm movements detected by IMU and hand movements detected by EMG, a sequence containing both was required. The motion sequence shown in Fig. 1 and performed in [1] was chosen, given its variety of movements, as well as to allow a comparison between both studies. The sequence is composed of 8 different dynamic movements, including both arm and hand movements, which are signaled in green. While some are clearly identified by numbers (#2, #4, #5, #7 and #8) the other 3 are movement epenthesis. They will throughout this manuscript be identified with a number according to their position in the sequence (#0.5, #2.5 and #5.5).

An important note to take from this sequence is that not all gestures are guaranteed to be detected by both the sensors of the armband, as some correspond to only arm gestures and some to only hand gestures, with the other sensor being an auxiliary source of information in those cases. The group of relevant gestures to be captured by the IMU sensor is R_{IMU} = [#0.5, #2, #4, #5, #7, #8] and the group of relevant gestures which are to be captured by the EMG sensor is R_{EMG} = [#2.5, #4, #5, #5.5, #7]. Gestures which only rely on arm gesture are O_{IMU} = [#0.5, #2, #8] and those which only rely on hand movement are O_{EMG} = [#2.5, #5.5].

A gesture segmentation process using a sliding window method was used to segment continuous data obtained from the IMU and EMG sensors. The sliding window method considers that there is motion if there are motion features above defined thresholds, thresholds calculated for each motion feature using a genetic algorithm as proposed in [1]. A sliding window is composed of *w* consecutive frames, being *w* the window size, and in each