FUSION OF EEG AND EMG SIGNALS FOR GAIT INTENT DETECTION

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***Abstract*: *Patients suffering from neuromusculoskeletal disorders and older peopleaim to increase their quality of life with the help of orthotic devices. But these devices are not yet smart enough to tackle the hassles of patients because they are lacking in fusion algorithm required for the optimal assistance. Therefore, these devices are not able to adapt the perturbations in intentions. The disturbance taken here is the fatigue. The hybrid fusion algorithm is explored to overcome this drawback. In the algorithm, the intent classification is done simultaneously from EEG and EMG signal. The ratio is maintained at the start of the cycle but as the fatigue increases EEG dominance increases with the same ratio. The multimodal fusion approach yielded stable and better results compared to the singular approach. A smooth transaction could be achieved even when the muscular fatigue is increasing.*

Keywords: *neuromusculoskeletal disorders, orthotic devices, EEG and EMG signal*

I. INTRODUCTION

The development of Brain-computer interfaces (BCIs) allows the disabled persons to interact with all the body functionaries to control the different body parts (Wolpaw et.al. (2002)). This interaction is interpreted by analysing the electrophysiological signals of brains recorded by the electroencephalogram (EEG).In recent years, there is an advancement in BCI technology but it cannot be compared with the EMG-based controls in terms of interaction speed and performance (Allison et.al (2007)). Therefore, the fusion of above two technologies will help the disabled population to use their control functionality optimally. In older people and in the early stage of amyotrophic lateral sclerosis, the mental and physical conditions of a person changes throughout day. So, the hybrid technology will take care both the conditions, sometimes with the muscle activity and in other with the brain signals in a proper proportion (Millán et.al.(2010); Pfurtscheller et.al (2010)).

The hybrid devices generally actuate different parts of the assistive devices using different control algorithm depending on the input or all the actuating parts could be controlled simultaneously so as to allow the assistive device to switch smoothly from one input channel to another depending upon their strength. Such type of hybrid device will improve the quality of life of a patient. The various hybrid BCI system is found in the literature such as motor imagery (MI) with a combination of steady-state visual evoked potential (SSVEP) based on multiple brain signals (Brunner et.al(2010)). When using the EMG signals alone, muscle fatigue problem is usually encountered. This not only affects the frequency and amplitude of the EMG signal but also distress the muscle contraction normal levels (Sadoyama et.al(1983); Hagberg et.al (1981)). This condition usually occurs in older people because in the older body the size of the skeletal muscle fibers reduces which results in strength reduction and fatigue occurs more rapidly (R. Martini (2000)). Throughout the day, the mental and physical conditions of these people changes and due to physical exhaustion muscular fatigue may occur. To tackle the effects of muscle fatigue, there is a need of an EMG-based control design. There are very few attempts (Artemiadis et.al (2011)), to develop an EMG-based control method robust to muscle fatigue. But only

EMG-based control cannot deal with the muscle fatigue conditions alone. So, EEG signal can be used as a surplus signal in the control algorithm as an input to deal with muscle fatigue (Leeb et.al. (2011);Leeb et.al(2010)).

This Paper explored the parallel fusion of EEG and EMG signals. The control inputs of both the input signals are fused, so that the control will be more reliable considering the level of muscular fatigue.

II. EXPERIMENTATION

2.1 Experimental Paradigm

Three healthy persons (male, age 24±3 years; height 5’5”±3”; weight 70±4kg) participated in this experiment. The task in this experiment is sitting to stand and stand to sit. The subjects repeated this task for 5 minutes. Simultaneous measurement of EEG and EMG is done during this activity. Biometrix system is used for measuring the EMG signal for EEG Biopac MP 150 is used. Both the signals were recorded using a sampling rate of 500 Hz. Experimental setup and electrode placement are shown in Figure 1.

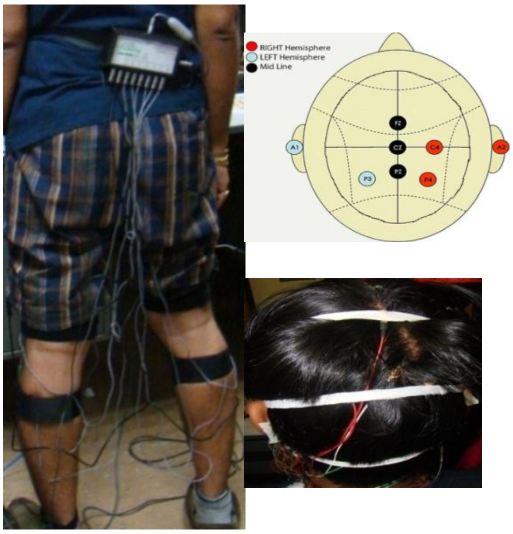


Figure 1: Experimental setup for EMG and EEG electrode position

2.2 EMG Processing

Three muscles are selected i.e. Rectus Femoris, Semimembranosus, and Gastrocnemius for extension and flexion during the above activity. The sampling rate of EMG signal acquisition is 500 Hz. From this signal, low-frequency noise is removed by removing the DC offset and high pass filtering is done with a cut-off frequency of 5-30 Hz. To get the envelopes, the EMG signals were rectified and averaged at 0.3 seconds. The activity was extracted during the non-execution period and thresholds were set which are the sum of mean and three times the standard deviation of the non-execution period (Leeb et.al(2007)). The activities larger than these thresholds were only used for the intention. RMS value of the signal is also calculated.

2.3 EEG Processing

10-20 electrode placement system is used for recording the electrical activity of scalp positions during the above activity. The scalp positions were Fz, Cz, C4, Pz and P4. The power spectral density (PSD) is calculated in 4- 48 Hz band and is calculated 16 times per second using Welch method with a Hanning window of 500ms.To train the Gaussian classifier (Galán et.al(2008); Millan et.al(2004)), only the features which are stable across the whole feature were used.

2.4 Simulation of Fatigue

In this experiment, the impact of the fatigue on the EMG is also calculated during the isometric condition. The fatigue is calculated by controlling the force using developed Intent Detection Sensor module (IDSM). The muscle forces were calculated at 100%, 75%, 50% and 30%. The EMG signal is reduced with the reduction of the force applied which is similar to the fatigue profile as shown in Figure 2. This makes the fusion of the EEG activity more important. Literature shows increased and decreased EMG as a sign of fatigue (Dimitrova et. al(2003); Gerdle et.al(2000)). An increase in the EMG amplitude is because of the additional motor unit recruitment is to compensate the decrease in force. But this amplitude increases for the short span of time and then it decrease gradually as the fatigue increases.

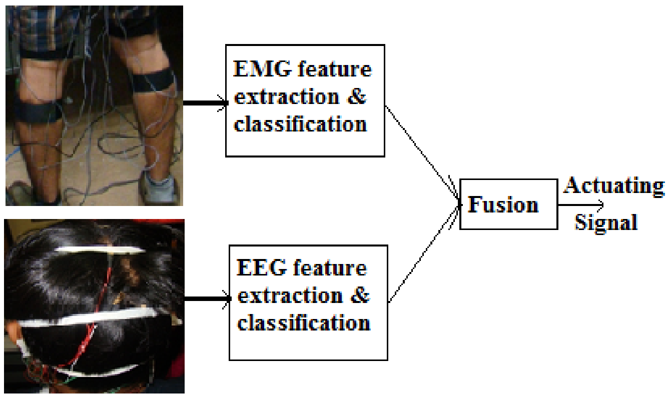


Figure 2: Simulation of Fatigue

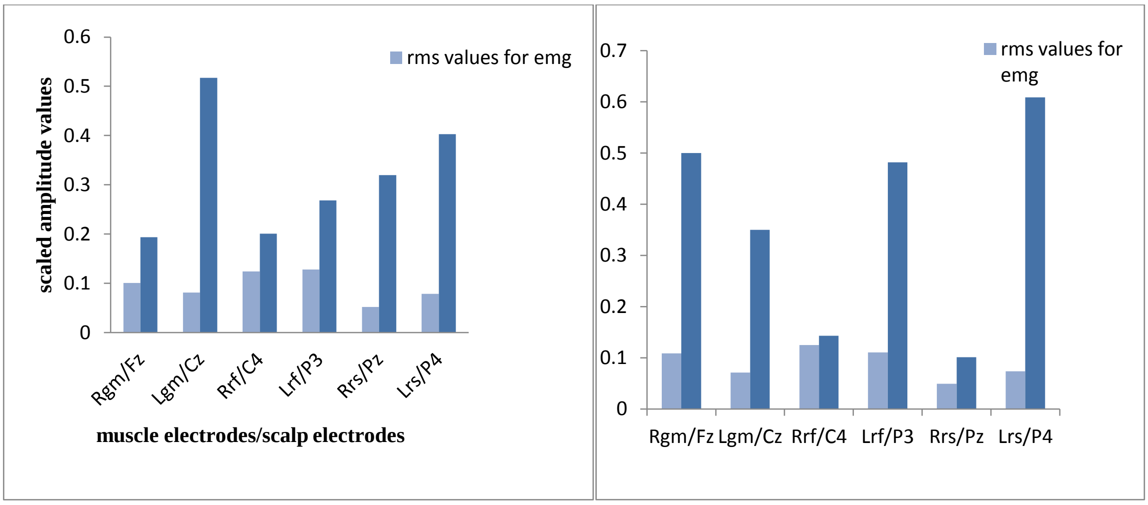
2.5 Fusion of EEG and EMG

The proposed fusion of EMG and EEG is based on the fact that the EMG decreases with the increase in fatigue. But, the EEG remains the same for that activity. The control algorithm is proposed to detect the intention by fusing both these signals. EMG is a strong signal as compared to EEG. So, EMG and EEG is used for the initialization of the gait cycle.But, as the fatigue increases, the EMG reduces gradually. So, the dependency on the EMG is reduced and on the EEG is increased by the same ratio as of fatigue.

III. RESULTS & DISCUSSIONS

The PSD and RMS of the EEG and EMG signals were calculated for the event classification during sit to stand and stand to sit conditions as shown in Figure 3. The EEG and EMG signal is also used to detect the position of the scalp for the intention i.e.

sits to stand and stand to sit. The corresponding consistent values of muscle and scalp position is used for the controlled strategy. Activities of both leg muscles were calculated and thecorresponding EEG fromthe scalps. The corresponding scalp position is Fz for rightgastrocnemius, Cz for left gastrocnemius, C4 for right rectus femoris, P3 for left rectus femoris, Pz for right semimembranosus and P4 for left semimembranosus. The RMS value of EMG has more strength than PSD of EEG. EMG proves to be the better input for actuation but as the EMG reduces due to fatigue EEG becomes more significant. Isometric contraction condition is used to calculate the fatigue level of the muscle.



(a) (b)

Figure 3: EMG and EEG signal for (a) sit to stand (b) stand to sit

Various Isometric conditions are used to calculate the muscle force as shown in Figure 4.The graph shows the decrease in the application of force, the muscle strength is also reduced. This decrease in muscle strength is proportional to the muscle fatigue. The level of muscle fatigue is calculated with the help of the experimental values calculated during the isometric contraction.

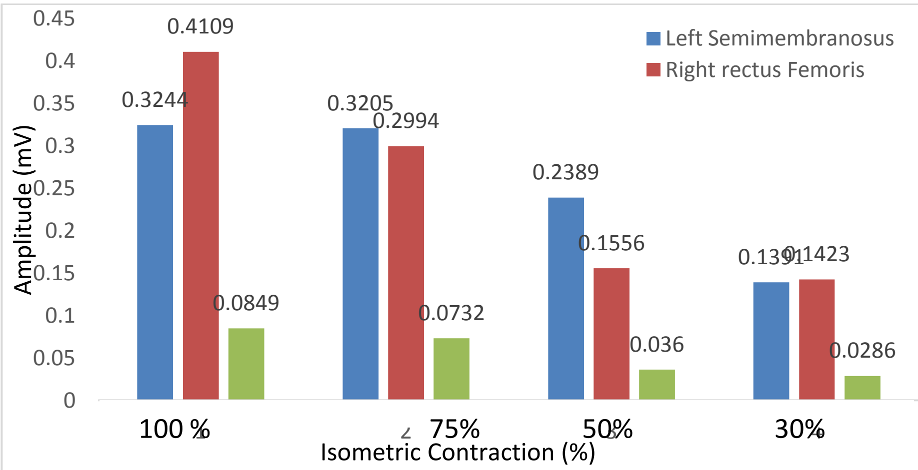


Figure 4: Muscles amplitude at different Isometric Conditions

Proper aspect ratio is maintained between the EEG and the EMG signals. Initially, the decision on the intention is calculated when both the input conditions are true. But as the level of fatigue increases the dependency on the EMG signal is reduced by the same proportion. And hence, the fusion control gives better and more stable performance.

IV. CONCLUSION

Multimodal fusion is used to achieve reliable and better performances. It allows the combination of brain control and other residual motor control to achieve a good control of functionalities independent of muscular fatigue level. The EMG controller alone is not reliable in case of fatigue. So, the EEG signal is also used as input to the control algorithm because it is not hindered by the fatigue.

The level of fatigue is calculated using IDSM under isometric condition. It tells the strength of muscles at different contraction levels. The hierarchical probabilistic approach is planned where each input signal is modelled independently, fused and exploits accordingly. This approach not only proportionally weighted the input signals smoothly but also monitored the physiological and mental states continuously.

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