A study on EEG based motion intention estimation techniques for control of upper limb wearable robots

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（脳波を利用した上肢装着型ロボット制御のための動作意思推定技術の研究）

区　　分　：甲

論　文　内　容　の　要　旨

Wearable robots can be used to supplement the function of a limb or to replace it completely. During the operation of these devices, it is important to control them to perform the functions that the wearer need to perform. This involves the identification of the correct motion intention of the wearer. Recently, brain computer interfaces (BCIs) are used to understand the human motion intention. Amongst different BCI methods, Electroencephalography (EEG) signals recorded from the scalp of the human are expected to contain information related to motion intention of the wearer. In most of the available studies with EEG, the motor imagery or motor execution by the subject that triggers the EEG pattern differs from the motion, generated by the robot. Most studies followed an approach to define a third-party brain trigger for a selected DoF or task. Further, only in a few of the studies, the subject operated a single DoF of the robot or the simultaneous operation of several DoFs was not possible, and did not provide an intuitive user experience. Accordingly, this thesis proposes different techniques to estimate the motion intention of the multi DoF of the human, in terms of intended tasks to perform. The studies are applicable to control of multi DoFs of exoskeleton or prostheses. The results demonstrated the effectiveness of the proposed methods to estimate multi-DoF motions of the human. This thesis consists of five chapters.

Chapter 1 explains the current status BCI systems. It initially presents the motivation for the current study. Later it introduces available wearable robotic technologies. It will be followed by the information of available control approaches for identification of motion intention from the human subjects. This will include an explanation about the available BCI based control techniques that will be followed by a description of the behavior of the brain. At the end of the chapter, an explanation about the outline of the current thesis is presented.

Chapter 2 is dedicated to propose a task based motion estimation technique. The key steps in developing a BCI to understand human motion intention can be identified as understanding the activation locations of the brain, understanding the main frequency ranges of brain activations, making the classifier understand the dynamic information included in the EEG signals and finally the estimation of the human motion intention. Accordingly, in this chapter, a new approach to control several degrees of freedoms (DoF) in a wearable robot is proposed by estimating the users motion intention in real-time, in terms of the user's intended tasks to perform, by using EEG signals measured from the scalp of the user. Information identified in an offline study are used to create time-delayed feature matrix, which constitutes of the power band features of EEG signals is introduced to provide inputs to the neural network and support vector machine based classifiers that harvest the dynamic nature of the EEG signals for motion intention prediction. In order to estimate the motion intention, individual classifiers are trained for each individual subject for both types of classifiers. At the same time, another two different classifiers are trained with data from all the subjects for the purpose of comparison. The estimation results from both types are presented in this chapter and compared. Similarly, prediction latencies are calculated for each technique and are presented with a comparison. As a conclusion, the experimental results indicated the effectiveness of the proposed methodology in the prediction of user's motion intention.

Chapter 3 is also dedicated to propose a task based motion intention estimation to control a transhumeral prosthesis. Robotic prostheses are expected to allow amputees a greater freedom and mobility. However, available options to control transhumeral prostheses are reduced with increasing amputation level. In addition, for electromyography-based control of prostheses, the residual muscles alone cannot generate sufficiently different signals for accurate distal arm function. Thus, controlling a multi DoF transhumeral prosthesis is challenging with currently available techniques. In this chapter, an EEG based hierarchical two-stage approach is proposed to achieve multi-DoF control of a transhumeral prosthesis. In the proposed method, the motion intention for arm reaching or hand lifting is identified using classifiers trained with motion-related EEG features. For this purpose, neural network and *k*-nearest neighbor classifiers are used. Then, elbow motion and hand endpoint motion is estimated using a different set of neural-network-based classifiers, which are trained with motion information recorded using healthy subjects. The predictions from the classifiers are compared with residual limb motion to generate a final prediction of motion intention. This can then be used to realize multi-DoF control of a prosthesis. The experimental results show the feasibility of the proposed method for multi-DoF control of a transhumeral prosthesis. This proof of concept study was performed with healthy subjects.

Chapter 4 presents the research work related to the velocity based motion intention estimation. Here two different approaches to estimate the user's motion intention in terms of velocity are proposed and their feasibility is evaluated and performance are compared. In the first method, the activation of the brain is identified in an offline study and the results are used to train a neural network based classifiers to estimate the 2 DoF motion velocity. This will enable the control of similar number of DoFs of the robot. In the latter method, to estimate the velocity of the hand end point, root mean square (RMS) based feature matrix introduced as input to the nonlinear autoregressive network with an exogenous input. Experiments were carried out to test and prove the proposed methodologies are presented in this thesis.

Chapter 5 includes a summary of the contributions of the thesis, the conclusion, a brief discussion, and suggestions for the future directions.