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博　士　論　文　の　要　旨

専攻名　　システム創成科学専攻

氏　名（本籍）　SENARATH WASALA HERATH MUDIYANSELAGE THILINA DULANTHA LALITHARATNE (SRI LANKA)

博士論文題名

A Study of Controlling Upper-Limb Exoskeletons Using EMG and EEG signals

（ EMG,EEG 信号を利用した上肢外骨格ロボットの制御に関する研究 ）

要旨（２，０００字程度にまとめること。）

Among the many fields of robotics, assistive robotic technologies have attracted a lot of attention among the research community as well as the common society. Especially assistive robots such as exoskeletons, prosthetics are playing major roles in assisting and rehabilitation processes for a range of people including physically weak, old, injured or disabled individuals to improve their quality of life. An upper-limb exoskeleton robot is one of the most effective assistive robots that can be used to assist or rehabilitate the motions of upper-limbs of a physically weak individual. Controlling upper-limb exoskeletons however, requires sophisticated technologies or methods, as they always interact with human users. More importantly, upper-limb exoskeletons are required to control according to the motion intention of the user. Apart from torque/force sensor signals, Electromyography (EMG) and Electroencephalography (EEG) signals are identified as two potential input signals for these control methods in order to monitor the motion intention of the exoskeleton users. Although there has been tremendous progress in the last decade in control methods for upper-limb exoskeletons, there are several problems which need further research effort. Therefore, the objective of this thesis is to address issues related to the control of upper-limb exoskeletons using EMG and EEG signals. More specifically this thesis focuses on the issue of muscle fatigue in EMG-based control and the feasibility of using EEG signals for evaluation of the perception-assist in upper-limb exoskeletons.

The first half of the thesis addresses the problem of muscle fatigue on EMG-based control. At the beginning, experiments were carried out to find out the effects of muscle fatigue on EMG signals and EMG-based control in human upper-limb power-assist. The results of these experiments revealed that only an EMG amplitude feature such as EMG Root mean square (RMS) is not adequate as an input for accurate EMG-based control during the muscle fatigue conditions and highlighted the importance of using frequency domain EMG features as additional input features to EMG-based control. To compensate for the effects of muscle fatigue on EMG-based control, this thesis proposed a novel method based on multiple fuzzy-neuro modifiers which used EMG mean power frequency (MPF) in addition to EMG RMS as an input to identify the muscle fatigue conditions. Experiments were performed with elbow flexion/extension motions to control a robot arm and the proposed method was able to reduce the overshoots of the robot motions that occurred due the effects of muscle fatigue conditions. From the overall analysis, it turned out that the proposed method based on multiple fuzzy-neuro modifiers with EMG RMS and MPF features as inputs could be effectively used to compensate for the effects of muscle fatigue on EMG-based control. With increasing number of EMG-based control approaches for assistive robots, the proposed method is beneficial to deal with the problem of muscle fatigue.

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The second half of the thesis investigates the feasibility of EEG signals for evaluation of the perception-assist control performed by the upper-limb exoskeletons. Perception-assist has been introduced in addition to the power-assist for upper-limb exoskeletons to avoid the undesired motion intentions by the users with deteriorated perception abilities. Perception-assist needs to be learned by the exoskeleton itself and in this learning process; it is required to judge the correctness or incorrectness of the perception-assist performed by the exoskeleton. EMG is one of the potential signals to judge the perception-assist control performed by the exoskeleton. On the other hand, EEG signals are also another candidate for evaluation of the perception-assist control. Experiments were carried out using a wrist assist exoskeleton with perception-assist while monitoring EMG and EEG signals. Results of the analysis of EMG signals during perception-assist signified that EMG signals are sometimes not adequately changed for the judgments of the perception-assist. Moreover, for a particular user, it might be difficult to measure the EMG signals or required muscles may simply be unavailable. For these reasons, in addition to EMG signals, this thesis explored the possibility of utilizing EEG signals. Correctness or incorrectness of the perception-assist was judged using a combination of EMG-EEG signals and the results showed a relatively higher accuracy compared to EMG signals alone. Moreover, an attempt was made to judge the perception-assist based on only EEG signals. Even though the accuracy of the judgment was above the chance level in this approach, it was lower than that of EMG only or EMG-EEG approaches. Therefore, this study suggested that to use a combination of EMG and EEG for higher judgment accuracy of the perception-assist. Moreover, it was highlighted that depending on the situation and condition of the user, either EMG, EEG or combination of EMG-EEG can be switched in between to judge the correctness or incorrectness of the perception-assist.