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論　文　内　容　の　要　旨

氏　　名　（　古川　淳一朗　）	
論文題名	Multi-channel Bio-signal-based Human Movement Estimation for Assistive Robot Control （多チャネル生体信号からのヒトの運動推定によるアシストロボット制御）

論文内容の要旨

Thanks to recent highly-developed control and sensor technologies, robot has become possible to assist human movement and work with human. For example, exoskeleton robots to assist human are actively investigated. A major feature of these robots is to physically interact with human. In particular, since the assistive robot is controlled by the user wearing it, the human state which changes dynamically has to be considered. Bio-signals have been extensively used to control assistive robot by estimating human movement intentions. For these applications, using multiple sensor channels is effective means to estimate user's movement intentions in detail. However, multi-channel bio-signal-based control has yet to be feasible in real world applications due to the difficulty of signal processing for the control. A robust estimation of human motor intention will be a promising approach for the high affinity robot control. In this study, I propose robust estimation methods of human motor intention from multi-channel Electromyography (EMG) or Electroencephalogram (EEG) to control assistive devices, and develop hardware and software to realize the systems.

In the EMG-based assistive robot control, estimating human joint torques robustly from muscle activities is the basic challenge. Most of conventional studies estimated joint torques from small number of electrodes based on a model calibrated by a data set corresponding to static load, and controlled the assistive robot with small degree of freedom. However, since the muscle activities are different between the static and dynamic motion, conventional data acquisition method cannot describe the relations between joint torque and EMG during motion. Furthermore, EMG electrodes might easily disconnected or detached from skin surfaces because human bodies are always in contact with the robot, and the probability of sensor electrode misplacement by human error also increases although multi-sensor electrodes need to be used to estimate multiple joint movements. Such sensor anomaly cause significant errors in the estimation of user movement and large unwanted interaction between the user and robot. It seems difficult to use many sensor channels to control assistive robots, although using multiple channels is useful to estimate human motor intention and control multi-DoF robot. In addition, if the exoskeleton robot assist human joint movement as the consequence of interaction, the human intentional joint torques are affected, and the original estimation cannot be used.

In this paper, I propose methods to deal with above problems. For the model calibration, torque-EMG data sets during dynamic motion are acquired by introducing inverse dynamics and bioengineering knowledge. Based on the data set acquisition, I propose robust estimation model using redundancy of the multi-channel bio-signals to control assistive robot with multi-degree of freedom by applying machine learning technologies. In addition, I also propose a controller considering human-robot interaction. As a result, multi-channel EMG-based exoskeleton robot could robustly assist human movement. Moreover, I try to control the assistive robots by the human brain activities. In general, EEG which measure brain signals in non-invasive is noisier than EMG, and it is difficult to capture the information of motor intention and control the assistive robot. For the EEG-based assistive robot control, real-time EEG-decoding and autonomous robot technologies are combined.

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論文審査の結果の要旨及び担当者

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論文審査の結果の要旨

申請者は多チャンネル生体信号から推定したヒトの運動意図に基づき、頑健にアシスト制御を行うヒューマンロボットインタフェースの構築とそれを実現するハードウェア開発を行った。ヒトと一体となるアシストロボットを生体信号により制御する場合、センサ信号の異常は推定精度を低下させ、ユーザーにとって危険なロボット動作を生成する。そこで本研究では、センサの異常度に応じて推定の寄与率を自動的に変化させる状態空間モデルを提案した。従来、センサの異常度はセンサ毎に検出されてきた。本研究で提案された手法では、正常時の多次元協調情報と現在の状態を確率分布間の距離を反映するKLダイバージェンスを用いて比較することにより抽出する。これによりセンサの断線、接触不良などの異常に加えて、従来の手法では検出困難であったセンサ情報の入れ替わり異常にも対処することができた。この研究成果は、これまでの生体信号を使ったロボット制御の実用上の問題点を打開するものであり、ブレインマシンインタフェースへの貢献も期待できる。以上の理由により、学位授与に値するものと認める。