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科研費 KAKENHI

科学研究費助成事業　　研究成果報告書

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研究課題名（和文）Estimation of human motion intentions using high density EMG signals

研究課題名（英文）Estimation of human motion intentions using high density EMG signals

研究代表者
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交付決定額（研究期間全体）：（直接経費）　　3,600,000円

研究成果の概要（和文）：外骨格や義手などのウェアラブルロボットシステムでは、装着者の動作意図を捉えることが重要です。高密度筋電図（HDEMG）を使用し、リアルタイムで人間の動作意図を抽出しました。人間の手は自由度が高いですが、従来の筋信号の計測や解析技術では、このような自由度に関連する情報を十分に得ることができませんでした。そのため、本研究ではHDEMGを用いて測定された人間の筋肉の空間的な活性度のばらつきが、より高い自由度の運動意図を高精度に推定するのに十分な情報を提供できることを示しました。

研究成果の学術的意義や社会的意義
This study will provide insights into how enough information related to multi DOFs of human moiton can be extracted from HDEMG for motion intention estimation, considering the spatial variations of the muscle activations. This will help to improve the quality of life of wearable robotic users.

研究成果の概要（英文）：In wearable robotic systems like exoskeletons and prostheses, capturing the motion intention of their wearer is crucial for intuitive control to supplement or support the intended motion. In this study, high-density electromyography (HDEMG) was utilized as a biological signal to extract human motion intention, focusing on a prosthetic hand user. The human hand possesses a higher number of degrees of freedom (DOFs). However, conventional muscle signal measurement and analysis techniques are inadequate to provide sufficient information related to this higher number of DOFs. This study demonstrated that variations in spatial activations of human muscles, measured with HDEMG can offer adequate information to estimate motion intention for higher DOFs with higher accuracy in real-time. Initially, the spatial information of the human muscles was mapped into heatmaps. Later, corresponding information related to the spatial changes in the heatmaps over time was used to estimate intended motion.

研究分野：Medical Robotics

キーワード：Wearable Robotics　Rehabilitation　Esoskeleton

Estimation of human motion intentions using high density EMG signals – 21K18105

１．研究開始当初の背景

Wearable assistive robotic systems require understanding users' motion intentions to offer intuitive assistance. Bio-signal modalities like EEG, fNIRS, or sEMG can capture signals from the nervous system, accessing information related to intended motions. However, technical challenges persist in interpreting the acquired data, particularly with a larger number of motions. In such cases, High-Density Electromyography (HDEMG) can provide measurements from a higher number of channels, offering comprehensive information crucial for motion classification.

２．研究の目的

Main objective of this study is to investigate how to successfully extract motion related information from the HDEMG signals for multiple degrees of freedom, considering the spatial variations of the electrical activity of the human muscles.

３．研究の方法

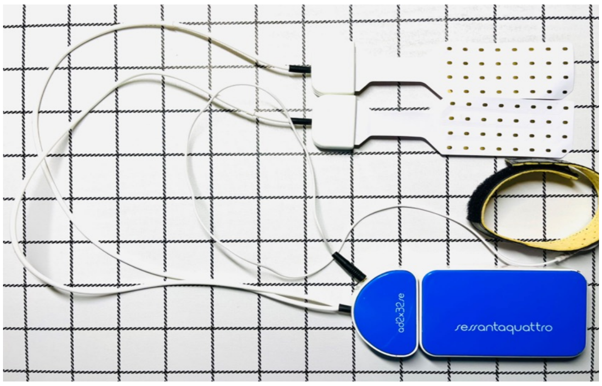

Figure 1- Sessantaquattro Otbioelettronica bio-signal amplifier, with 2 x 32 HDEMG electrodes

Figure 2 – experimental setup

In the current study HDEMG signals were measured and recorded using the Sessntraquattro – Otbioelettronica bio-signal amplifier and 64 channel electrode grids. The device is shown in Fig. 1. The device can capture 64 channels of HDEMG signals at a 2000Hz sampling frequency. In this study motion intention for hand and figure motion were carried out to test the proposed method. An example of the experimental stup is shown in Fig. 2. Electrode grids are placed on the interested muscles of the human forearm. Motions commands are displayed on a screen in front of the subject to be followed. Initially, the study was carried out in an offline mode, to understand how the motion related information can be extracted from HDEMG signals.

Thus, this study proposed to use the spatial changes in the muscle activity to be used as information for the motion intention estimation. We assumed, spatial changes during motions play a pivotal role in understanding the intricate muscle activation patterns across the muscles during various motions. Accordingly, we investigated how to comprehend the information within HDEMG by analyzing spatial changes in muscle activation during various motions. We initially, pre processed the recorded HDEMG signals to remove artifacts and noises. Then we calculated the root mean square (RMS) values for each channel for selected window lengths. These calculated RMS values mapped by rearranging the electrode numbers to be correspond to the placement of the electrode grids.

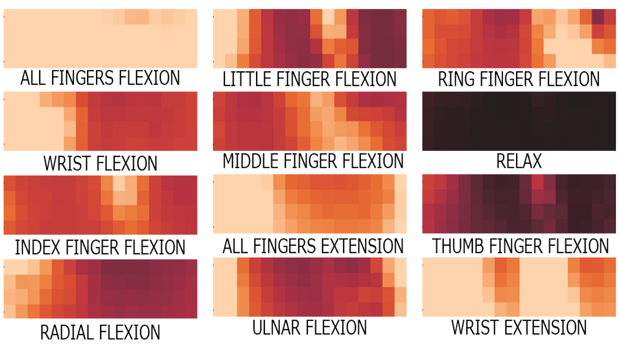

Figure 3 - Spatial variations of the muscle activity at its peak variation for different motions

With this heatmap images were generated to represent muscle activations based on the RMS values of the EMG channels. Heatmaps generated for 12 different motions in one of the experiments are shown in Fig. 3. As can be seen in the heatmaps, the muscle activations show different activation pattern during different finger motions. In the next step of the study, we introduced commonly available feature extraction techniques in image processing techniques such as Gabor filters and histogram of gradient (HOG) features to process these images and extract the information related to the color changes corresponding to the muscle activation.

4． 研究成果

Subjects	1st	2nd	3rd	4th	5th	6th	7th	8th
Total (k=5)	92.2	98.6	98.5	91.7	99.3	88.4	95.5	95.8
Fingers flex	100	98.6	84.1	96.9	94.1	75.0	96.1	98.6
Index flex	97.8	97.9	100	56.9	99.4	98.7	99.3	97.9
Middle flex	100	100	100	100	100	100	99.4	100
Ring flex	88.6	99.4	100	99.3	100	94.9	100	99.4
Little flex	99.3	96.7	100	95.3	100	85.8	100	96.7
Thumb flex	56.3	99.4	100	100	100	100	100	99.4
Radial flex	81.8	84.4	100	98.0	98.2	76.1	96.9	84.4
Ulnar flex	100	86.5	99.3	98.2	100	88.0	99.3	86.5
Wrist ext	100	85.9	96.2	85.1	100	93.2	98.8	85.9
Wrist flex	100	100	100	99.4	100	68.9	90.4	100
Relax	100	100	100	100	100	100	100	100
Fingers ext	81.3	95.3	96.8	81.2	100	76.4	73.7	95.3

Figure 4. Classification results for offline study with 8 subjects

Using such extracted features, we employed machine learning techniques such as support vector machine (SVM), error correcting output codes – SVM (ECOC-SVM) to classify the motion. The lates offline study showed an average accuracy of 95.0% for the 12 hand motions for all 8 subjects, in combination with HOG features and SVM classifier for 5 fold cross validation. The detailed results are shown in the table in Fig. 4. In the next stage we extended the study to a real-time approach with the same basic configuration as learned during the offline study. An average accuracy of accuracy of 78.4% for 8 subjects for 12 hand motions were obtained for the real-time approach. The average prediction delay was 90ms, proving the effectiveness of the proposed approach in real-time application for wearable robotic applications. In the next stage of this study we expect to extend the proposed studies to estimate simultaneous, proportional joint movement, related to the human motion intention.

	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
Relax	85.6	50.6	78.0	50.4	38.4	32.2	40.6	37.5
Index flex	66.4	70.6	84.6	64.7	97.2	79.4	61.7	66.7
Middle flex	87.2	83.0	92.3	81.7	92.2	88.2	74.1	76.3
Ring flex	81.8	64.0	94.1	84.0	96.3	74.5	55.8	76.5
Little flex	77.3	70.4	90.0	78.5	86.3	71.9	59.6	82.3
Thumb flex	87.2	77.8	84.6	78.0	99.6	81.8	51.2	90.0
Fingers ext	89.4	71.3	92.3	87.6	86.1	76.5	62.2	81.1
Fingers flex	86.3	66.5	94.1	92.5	93.3	78.5	50.8	85.6
Radial flex	87.7	67.5	90.0	84.8	96.7	80.4	52.1	86.0
Ulnar flex	89.4	74.3	84.6	88.5	97.4	81.9	71.9	88.7
Wrist ext	79.5	63.0	92.3	87.1	95.5	77.5	75.7	83.6
Wrist flex	90.0	83.9	94.1	87.0	93.5	87.2	59.8	86.7
Overall	84.0	70.2	89.2	80.4	89.4	75.8	59.6	78.4

Figure 5. Classification results for real-time study with 8 subjects

In conclusion, this study demonstrated that the human muscles show spatial variation in their electrical activity for different motions. HDEMG signals could successfully measure these spatial variations of electrical activity of the muscle. Information extracted from these spatial variations demonstrated they can successfully provide enough information to estimate human motion intentions, when employed with suitable signal processing and machine learning algorithms. Next stage of this study will investigate how to successfully use these information to estimate simultaneous motions, continuously related to human motion intentions in real-time.

５．主な発表論文等

〔雑誌論文〕　計0件

〔学会発表〕　計4件（うち招待講演　0件／うち国際学会　2件）

１．発表者名 D.S.V Bandara
２．発表標題 Motion intention estimation of finger motions with spatial variations of HD EMG signals
３．学会等名 International Conference on Computer and Automation Engineering 2023（国際学会）
４．発表年 2023年

１．発表者名 He Chongzaijiao
２．発表標題 Prediction of finger motions based on high-density electromyographic signals using two-dimensional convolutional neural networks
３．学会等名 39th annual conference of the Robotic Society of Japan
４．発表年 2023年

１．発表者名 D.S.V Bandara
２．発表標題 Estimation of human motion intention with HDEMG for wearable robotic applications
３．学会等名 37th annual conference of the Robotic Society of Japan
４．発表年 2021年

１．発表者名 D.S.V Bandara
２．発表標題 Classification of hand motions using spatial information in HDEMG signals with HOG features
３．学会等名 International Conference on Computer and Automation Engineering 2024（国際学会）
４．発表年 2024年

〔図書〕　計0件

〔産業財産権〕

〔その他〕

- Visited Department of Biomedical Engineering and Department of Mechanical Engineering of The University of Melbourne, shared the recent research interests/results and sought possible future collaborations between Kyushu University and The University of Melbourne.

6．研究組織

	氏名 （ローマ字氏名） （研究者番号）	所属研究機関・部局・職 （機関番号）	備考

7．科研費を使用して開催した国際研究集会

〔国際研究集会〕　計1件

国際研究集会	開催年
A seminar on Innovative Approaches for Assistive Robotic Limbs - Prof. Ruwan Gopura (University of Moratuwa)	2023年～2023年

8．本研究に関連して実施した国際共同研究の実施状況

共同研究相手国	相手方研究機関