

論文 / 著書情報
Article / Book Information

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Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

(博士課程)
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論文要旨

THESIS SUMMARY

系・コース： 情報通信 系
Department of, Graduate major in ライフエンジニア リング コース

申請学位 (専攻分野) : 博士
Academic Degree Requested Doctor of (Philosophy)

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要旨 (英文 800 語程度)

Thesis Summary (approx.800 English Words)

Upper limb amputees will lose their ability to work and even have trouble maintaining a normal life. To improve the life quality of upper limb amputees, the control strategy of myoelectric prosthesis with high accuracy and robustness is necessary. Much research considered applying deep learning for forearm motion classification or regression. However, even until now, most of them were limited to offline analysis, and rare research proposed deep learning-based real-time control system, and most of them are related to motion classification. Thus, in this thesis, I hope to complete the following main tasks:

- Propose a deep learning-based regression model for motion recognition.
- Apply the proposed model on a real-time control system.
- Demonstrate the successful control by controlling a virtual hand based on the proposal.

In the first study, a channel-wise CNN (CW-CNN) regression model was proposed. Considering that the control of a prosthetic hand is actually the control of motors by control commands, joint angles in different degrees of freedom (DOFs) was used as the prediction target and designed the corresponding models and experiments. For model training, the surface electromyography (sEMG) signal and joint angles were acquired simultaneously as dataset by lab streaming layer (LSL), and the model accuracy was evaluated by correlation coefficient (CC). As the sEMG signal quality changes on different days, which can degrade the model performance, transfer learning was applied to update model. With the multi-array electrode sleeve, we do not need to adjust the electrode location for each subject, therefore, only FC layer parameters were updated during transfer learning. Experiments were designed in different days to prove the effect of transfer learning, and comparison between the proposed model and conventional regression models was discussed. The experimental results shown CC values of wrist flexion/extension was 0.8838 ± 0.027 , wrist pronation/supination was 0.8713 ± 0.0284 , hand grip/open was 0.8439 ± 0.0297 , respectively. With proposed layer transfer method, the CC results were improved to 0.9272 ± 0.0216 , 0.9248 ± 0.0321 and 0.8918 ± 0.0369 , respectively. Moreover, the comparison results between proposal and four conventional regression models demonstrated that the proposed CW-CNN model significantly outperformed with and without transfer learning.

Next, to investigate the real-time performance, a real-time control system using the proposed CW-CNN model was built. The sEMG signals were processed to integrated EMG (IEMG) signals in a real-time sliding window, and the joint angles were estimated by proposed regression model. Due to the lower sampling rate in real-time situation, oscillations could be observed in the output angles, which may damage the motors. Thus, Adaptive Kalman Filter was considered to smooth the outputs and used them as system outputs. The system outputs were sent to a virtual hand for real-time control tasks. To evaluate the system performance, CC was used again to analyze the real-time accuracy, and one-way ANOVA was used to prove the stable computational latency. To challenge the difficulty of real-time regression prediction compared to classification, three tasks of target achievement control (TAC) test were designed to emphasize the 3-DOFs motions. Participants operated the virtual hand using their forearm sEMG signals to complete not only TAC test but also thirteen daily motions, which demonstrated the usability of the proposed real-time control strategies that it can be applied to prosthetic hand in the future.

In this dissertation, I am committed to achieve the goal of proposing a real-time control strategy for myoelectric prosthetic hand with high accuracy and natural performance. This research made the following contributions:

● **In first research**

1. A CW-CNN regression model was proposed for daily motion estimation in 3-DOFs (WF/WE, WP/WS and HG/HO);
2. It was demonstrated that the model performed the best compared to another regression models;
3. A transfer learning strategy was proposed to update model on different days, and proved that the proposed layer transfer method can maintain and even improve the model robustness;
4. Based on the channel-wise convolutional layer, the motion patterns were explained via geometry plot by backtracking FC layer.

● **In second research**

1. A real-time control system based on CW-CNN model for virtual hand control was proposed;
2. Experimental results show that the system obtained good performance for both single and mixture motions;
3. Our system has an acceptable (74-75 ms) and stable (p-value>0.5) computational latency;
4. Simultaneous 3-DOFs motion regression was proved in real-time by TAC test.

The above contributions demonstrated the usability of the real-time control strategies for virtual hand. In the future, the proposed approach can be applied to a practical myoelectric prosthetic hand.

備考：論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。

Note: Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1copy of 800 Words (English).

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