Intra-cortical Brain Computer interface systems based on advanced digital signal processing techniques

by

Sofyan Hammad Himaidan Hammad

Intra-cortical brain-computer interface (BCI) is a relatively new technology that aims at improving the quality of life of severely disabled persons. The BCI systems work by interpreting acquired brain activity to drive the external devices. Intra-cortical recording methods have the advantage that they acquire highly specific information about a movement with very low latency. The earlier intra-cortical BCI systems traditionally rely on spike-sorting (sorting of single unit action potentials) with a high computational demand to extract information, and have shown to work mainly in restricted and well-controlled environments. This thesis hypothesized that movement intention can be decoded from non-spike sorted, intracortical recordings obtained from freely moving animals.

To address this hypothesis four studies were conducted. Rats were instrumented with intra-cortical electrodes, and brain signals were acquired while the animals performed an on/off type hitting task with the forelimb. Study 1 investigated the need for preprocessing and the effect of automatic spike-thresholding on the detection of the movement intention. The need for preprocessing emerges due to the noise present with the multi-unit recordings from freely moving subjects. It was found that a preprocessing step before movement detection was needed, but there was no difference was found between automatic and fixed thresholding. Study 2 evaluated the effect of denoising on the detection accuracy of the movement intention. Wavelet denoising was found to significantly improve the accuracy of movement detection. The aim of study 3 was to compare different detection methods. The results showed that the detection method had no effect on the detection accuracy, which allows the utilization of different detection methods. In Study 1-3, only one feature (the firing rate) was used as a basis for the detection. In Study four, it investigated if combining more features could improve the detection accuracy. Thus, combinations of seven features evaluated over three window lengths were investigated in a simulated real-time experimental setup. The combination of features and short window lengths was found to yield more stable and higher detection accuracies.

In this thesis movement intention could be detected with an acceptable accuracy from non-spike sorted intracortical recordings obtained in freely moving paradigm. The movement investigated was a simple ‘on-off’ hitting task, but the work indicates that with a careful choice of signal processing methods it is possible to overcome noisy signals and unpredictable environments and thereby design more autonomous intra-cortical BCI systems in the future.

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Ph.D. lecture

by

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Friday 2 March 2018

DEPARTMENT OF HEALTH SCIENCE AND TECHNOLOGY

AALBORG UNIVERSITY

This thesis is based on Sofyan Hammad Himaidan Hammad’s research work at:

SMI

Department of Health Science and Technology

Aalborg University

Denmark

To fulfill the requirements for the Ph.D. degree, Sofyan Hammad Himaidan Hammadhas submitted the thesis: Intra-cortical Brain Computer interface systems based on advanced digital signal processing techniques, to the Faculty Council of Medicine at Aalborg University.

The Faculty Council has appointed the following adjudication committee to evaluate the thesis and the associated lecture:

Associate Professor Aleksandra Vuckovic
University of Glasgow
Scotland

Senior Medical Affairs Project Manager
Omar Feix do Nascimento
Coloplast
Denmark

Chairman:
Associate Professor Natalie Mrachacz-Kersting
Aalborg University
Denmark

Moderator:
Associate Professor Cristian Sevcencu
Aalborg University
Denmark

The Ph.D. lecture is public and will take place on:

Friday 2 March 2018 at 13:00
Aalborg University – Room D2-106
Fredrik Bajers Vej 7 D2
9220 Aalborg East

Program for Ph.D. lecture on

Friday 2 March 2018

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Chairman:	Associate Professor Natalie Mrachacz-Kersting
Moderator:	Associate Professor Cristian Sevcencu
13.00	Opening by the Moderator
13.05	Ph.D. lecture by Sofyan Hammad Himaidan Hammad
13.50	Break
14.00	Questions and comments from the Committee Questions and comments from the audience at the Moderator’s discretion
16.00	(No later than) Conclusion of the session by the Moderator

After the session a reception will be arranged