Advanced Bayesian Neural Network Classifiers of Head-movement Directions for Severely Disabled People

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by

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CERTIFICATE OF AUTHORSHIP/ORIGINALITY

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of the requirements for a degree, except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Abbreviations

ANN .... Artificial neural network
ADC .... Analog to digital converter
BNN .... Bayesian neural network
BCI .... Brain computer interface
DGF .... Direction of greatest freedom
EWCI .... Eye-wink control interface
EEG .... Electroencephalogram
EMG .... Electromyography
FNS .... Functional Neuromuscular Stimulation
IDDM .... Insulin-Dependent Diabetes Mellitus
MLP .... Multi-layer perceptron
PCA .... Personal-care assistance
SCI .... Spinal-cord injury
SNN .... Standard neural network

Abstract

Assistive technologies have been dedicated to providing additional accessibility to individuals who have physical or cognitive difficulties, impairments and disabilities. Various types of assistive technology products are also available on the market today. However, there are still a significant number of disabled people who are unable to use commercial assistive devices due to their high level of injury.

For severely disabled people with quadriplegia resulting from high-level spinal-cord injuries or cerebral palsy, hands-free control methods have become extremely beneficial for them to reducing their dependence level in daily activities. In this control mode, head movement has been shown to be a very effective, natural and comfortable way to access the device. The need to exactly detect intentional head movements of various forms of disabled people has led to the use of neural networks. Recently, Bayesian neural networks have been proposed for developing neural network applications with finite and/or noisy training data.

In assistive technologies, power wheelchairs are a means of providing independent mobility. This thesis explores the useful properties of Bayesian neural networks in developing an optimal head movement-user interface for hands-free power wheelchair control systems. In such systems, a trainable Bayesian neural network is used to detect head movement commands. This kind of user interface can conveniently be used by various disabled users. The thesis also proposes the techniques for developing the adaptive Bayesian neural network for head movement classification, including the determination of the optimal architecture and the most effective on-line training algorithm for the network.

The experimental results obtained in the thesis show that a Bayesian neural network can be used to detect head movements accurately and consistently. After on-line training, the network is able to adapt well to the head movements of new users. The substantial contributions of the thesis can briefly be summarised as follows:

- Standard methods of neural network training usually require intensive search for network parameters or require the use of a validation set separated from the available training data. In contrast, in this thesis all the available training data have been used to train the network for detecting head movements. As the network could be trained on all the data from a group of different individuals, it is able to classify their new head movements with a very high accuracy, of 99.38%.

- The thesis strongly focuses on advanced training algorithms suitable for Bayesian neural network head-movement classifiers. Especially, the quasi-Newton training and scaled conjugate gradient algorithms have been found to be the most effective, as they can result in the shortest training time for the network.

- In general, the determination of the best network architecture is very difficult and is traditionally based on ad hoc methods. However, this thesis utilises the property of the maximum evidence, which is available in Bayesian neural networks, to select the optimal network architecture. Specifically, the networks containing three hidden neurons are appropriate for successful head-movement classification.

- The thesis also provides a novel method of early stopping in neural networks. In this method, the maximum evidence can be seen as a good criterion to terminate the training process before the network overfits the data. In addition, the use of a validation set for monitoring the generalisation error is no longer needed. Moreover, this thesis shows that the combination of independent Bayesian neural networks can significantly improve the head-movement classification accuracy.