誤り関連電位を用いたP300 BCI speller の実用性向上研究

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＜要旨＞

The objective of this research is to study the possibility of developing practical and efficient communication tool via brain computer interface (BCI) for people with neuromuscular disorder using P300 speller. Though P300 is now increasingly used for research as one of the applications of BCI, it has some drawbacks for practical application, mainly low reliability/accuracy, low speed and difficulty in use. In the proposed research I planned to investigate efficient detection of Error potential (ErrP) and how it can be used to improve the performance of P300 by optimizing accuracy and speed. Error Potential (ErrP) is another event related potential which is generated when the machine recognizes incorrectly which means it behaves differently from the user's intent. Incorporating ErrP for correction of the recognition error, the performance of P300 is expected to be improved so that commercial applications can be developed.

1　研究の概要

In the past few decades, P300 based Brain Computer Interface (BCI) paradigm has been developed and P300 speller paradigm (originally developed by Farwell-Donchin) is the most widely researched tool for people with diseases which impair them to communicate in a normal way. Though several drawbacks of the system have already been identified and researchers have tried to improve, it is yet to move to outside laboratories into practical applications.

The experiments with P300 BCI speller revealed the following shortcomings : 1) Due to very low amplitudes of P300 in EEG, averaging on number of flashes is required for high accuracy, thereby degrading the speed 2) The response is highly dependent on user 3) The response is affected by the design of the visual speller paradigm (row/column, single column or region based) and fatigue of the user after several trials.

It has also been found that another relevant event related potential known as Error Potential (ErrP) is generated when the machine makes a mistake in understanding user's intent. ErrP is a negative shift in the electric potential over the fronto-central region (from Fz to Cz of the 10-20 system) occurring 50-100 ms after an erroneous response (error negativity - Ne) and a subsequent positive shift in the parietal region whose maximum occurs between 200 and 500 ms after the error (error positivity - Pe).

From the above findings, it seems to be worth studying the possibility of 1) automatic detection of errors made by BCI speller in recognizing user's

intent 2) and a way to improve speller performance by automatic error correction and thereby overcoming drawback (1) listed above. As the ErrP is also person dependent, the incorporation of ErrP in error correction will partly remove the second drawback. For overcoming the third drawback, appropriate design of visual speller paradigm remains to be studied.

To fulfill the above objectives, initially a literature survey and a planning for experiments to detect ErrP has been done which is reported here.

2 研究の内容

In the present research, an extensive literature survey has been done to find out the present direction of research in this area, status of research results using error potentials for improving recognition accuracy of BCI instruments. A partial list of important articles is presented in the reference section. The summarization of research results on use of ErrP for improvement of the recognition accuracy of P300 BCI speller has been done. A review article on the state of the art of research on error potentials for improvement of BCI applications has been submitted for publication.

As the detection of low amplitude error potentials are difficult from EEG recording in a single trial, proper processing techniques are needed. For developing efficient processing techniques, EEG signals are recorded by Netstation system 300 for experimental analysis. The signals are analyzed with MATLAB software for experiments.

As error potentials are known to vary from person to person and channel to channel, experiments are done for selecting proper channels which can show strong signals for a particular person. These experiments have been done with BCI data on the web (Ref 9) and feature selection algorithms are tried for efficient channel selection.

3 これまで得られた研究の成果

From the literature study, it has been found that error related potentials are detected in the recorded EEG of a subject just after an error occurs (Ref 2). It is also known that error related potentials are usually followed by event related negativity and positivity present in the alpha band in the fronto-central channels. Based on the nature of feed back, the error related potentials can be categorized as response error potential, feedback error potential, observation error potential. The nature of the signals and their occurrences are slightly different.

In addition Ferrez (Ref.2) also confirmed with experiments the existence of the most interesting kind of error potential, Interaction Error potentials (IErrP) which are present when a device delivers an erroneous feedback. It is only triggered when the users are convinced that they have done everything right but the interface made an error for interpreting the command.

IErrP is generated due to the misclassification error of the BCI interface. It is characterized by an early negative voltage over the fronto-central region (from Fz to Cz in 10-20 system) followed by a larger positive voltage in the parietal region 270 ms and 350-450 ms respectively after the BCI feedback. Now the detection of this component in single trial is not easy as it is also noisy and low amplitude signal and setting up of proper experiments and processing mechanism is needed for its correct detection. So proper detection of IErrP signal and pinpoint the channels for strong IErrP is very important for designing efficient BCI application with higher performance.

From the experiments with 13 subjects in research work of Ref. 11, it has been shown that ErrP is a

powerful tool to improve the performance of existing BCI systems, 12 of 13 subjects showed expected results of the existence of interaction ErrP. It was also observed that even with a lower detection rate, IErrPs significantly improve the initial accuracies of participating subjects.

It can be concluded from the extensive study of the existing research works that detection of IErrp can help to construct more robust BCI by correcting BCI output directly with feed back from IErrP.

The experiments with collection and analysis of EEG signals for classification and feature selection with machine learning techniques are still ongoing and yet to produce efficient results.

4　今後の具体的な展開

In the next step, proper experimental set up has to be designed with g.TEC P300 speller for detection of error signals during decoding error of the speller. The objective of the design will be to record the action of the user after an error of the interface and EEG will be recorded. The experiments for channel selection and enhancement of signal for correct detection should be done.

Efficient Machine learning algorithm for feature selection (channel selection) and classification for IErrP detection should be devised.

5　論文・学会発表等の実績

Part of the results have been presented in Ref 10 and in a lecture delivered in Department of Computer Science, University of Washington, Seattle, USA.

Currently, a review paper on the status of research on the use of error potential in improvement of BCI is under progress.

6　受賞・特許

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