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Article / Book Information

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Title(English)	A Study on Visual Stimulus Increasing Event-Related Potentials and Computer Interfaces Using EEG
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種別(和文)	論文要旨
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（博士課程）
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論 文 要 旨

THESIS SUMMARY

専攻： Department of	Mechanical and Environmental Informatics 専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of (Engineering)
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要旨（英文 800 語程度）
Thesis Summary (approx.800 English Words)

Brain-computer interfaces (BCIs) have been actively researched for over two decades. One of the primary goals is to create a non-muscular communication channel for locked-in patients. Electroencephalography (EEG) is a non-invasive technique that is commonly used in BCI measurement systems. Even though BCIs have a long history, their performance is still limited by the low signal-to noise ratio of EEG. A state-of-the-art BCI application is P300-based BCI. P300 refers to a major event-related potential (ERP) component that peaks around 300 ms after visual stimulus. P300 is an electroencephalographic correlate of target recognition in decision-making tasks. The P300 is used in several brain-computer interfaces (BCIs) as a non-motor signal of decisions, such as letter choice in the P300-Speller utility. Accuracy in choice specification depends on the difference in P300 amplitude evoked by target versus non-target stimuli. In this thesis, I describe visual stimulus factors, *color, motion-modulated, complexity-modulated* and *orientation-modulated*, all of which enhance the difference in P300 magnitude between target and non-target stimuli for P300-based BCIs. Stimulus arrays incorporating these visual factors may be used for the design of improved P300-based BCIs with greater choice accuracy and speed.

To demonstrate advantage of research findings from visual factor studies, I report the development of a personal identification number (PIN) application using a P300-based BCI. I focus on visual stimulation design for increasing the evoked potential in the brain. Single-channel electroencephalography and a computationally inexpensive algorithm are used for P300 detection. Experimental results showed that my proposed stimulus induces higher P300 amplitude than does a conventional stimulus. For a performance evaluation, I compare two versions of the proposed application, which are based on my `original P300 BCI' and `adaptive P300 BCI'. In the adaptive P300 BCI, I introduce a novel algorithm for P300 detection to improve the information transfer rate while maintaining acceptable accuracy. Experiments with 10 healthy participants reveal that the original P300 BCI achieves mean accuracy of 83.5% at 11.4 bits/min and the adaptive version achieves mean accuracy of 86.0% at 18.6 bits/min.

On the basis of BCI and PIN application, I expand my research to hybrid BCI. Here, I propose a hybrid brain/blink computer interface based on a single-channel EEG amplifier. Eyelid closing and hard blink are selected as two possible inputs for control of the interface. A 2-min calibration is required before starting to use the interface. An algorithm for feature extraction and classification is developed for EEG signals from eyelid closing, hard blink, and resting. To evaluate the performance of the interface, I incorporate it into a personal identification number (PIN) application, in both visual and auditory modes. Experiments with 5 healthy participants reveal that the PIN application based on the interface achieved a mean accuracy of 97.4%. In conclusion, I expect that my investigation will contribute to hybrid brain-computer interface research and technologies in the near future.

At the end of this study, I start side project for future works. I develop a hybrid BCI for drowsiness detection using EEG and electrooculography (EOG). Measurement is done with a single-channel EEG amplifier. A simple responsive task performs in a drowsy environment is used to experimentally demonstrate the advantages of the proposed system. Additionally, I perform the first investigation of hybrid EEG/EOG indices for drowsiness detection. Pearson's correlation analysis reveals that hybrid EEG/EOG indices are better correlated with the Karolinska Sleepiness Scale (KSS)---the standard subjective measure---than are conventional EEG or EOG indices. My investigation could contribute to both sleep research and the development of real-time drowsiness detection in the near future.

This thesis consists of eight chapters. I begin with research motivation and background knowledge in Chapter 1. Chapter 2 covers a survey of the research related to P300-based BCIs using visual stimulation, hybrid BCIs and BCI applications. Finally, I emphasize my research position towards BCI research fields. Chapter 3 presents visual stimulus studies. Here, I focus on characteristics of P300 responses from several visual factors. Experimental results can be implemented as fundamental visual stimulus design knowledge for P300-based BCIs. In Chapter 4, I incorporate research findings from Chapter 3 into PIN application. Moreover, novel algorithm for P300 detection is reported in this Chapter. Finally, performance evaluation of PIN application using proposed P300-based BCI has been performed. Hybrid Brain/Blink is introduced in Chapter 5. To extract and classify feature signals from brain waves and blinks, novel technique and experimental study are demonstrated in this Chapter. Proposed hybrid interface is applied to PIN application. Evaluation of the proposed hybrid interface is performed through two modalities of PIN application (visual and sound navigated systems). In Chapter 6, the same recording system as Chapter 5 is used for feasibility study of drowsiness detection. Preliminary results have been promising for future studies. Chapter 7 discusses the contributions of this thesis and remaining issues for future works.