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Recent advances in VEP-based BCI systems

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Preface

This book presents the results of several projects coordinated and undertaken at the Rhine-Waal University of Applied Sciences at campus Kleve, located in 47533 Kleve, Germany (funded under the acronyms ABCI, EBCI, BCI@HOME and M3S within national and European research programs with the funding IDs 16SV6364, 01DR14014, GE-1-1-047, IT-1-2-001). The main focus of this book is the rapidly developing modern technology called Brain-Computer Interfaces (BCIs). BCI is based on the analysis and decoding of brain activity to provide a non-muscular channel for sending messages and commands to the external world. A field of BCIs emerged few decades ago as a new communication pathway allowing subjects with severe neuromuscular disorders, who may be completely paralyzed or locked-in, to communicate and interact with the outside world. Very recently, BCI applications have also been used in entirely different areas (e. g. entertainment). Between many different BCI paradigms, BCIs based on visual evoked potentials (VEPs) have shown their potential to be suitable for high-speed human-machine interaction with great accuracies. Recent advances in this area cover updates in signal-processing-algorithms used for the classification of old-fashioned Steady State Visual Evoked Potentials (SSVEP, also called f-VEP), where each target shown to the BCI user flickers with a unique constant frequency. It further extends not only to the more recent code-modulated Visual Evoked Potentials (c-VEP, where instead of using constant flickering frequencies, the visual stimulus is a pseudorandom swapping of orthogonal patterns), but to modern variants such as modern motion-onset visual evoked potentials (mVEP), flicker free steady-state motion visual evoked potentials (FF-SSMVEP) etc. Therefore, one of the main goals of this book is also to show the last research advances in BCI systems based on VEP, modern applications based on this BCI technique, as well as innovative signal processing algorithms or novel paradigms that make them possible. In addition to improving BCI system performance in terms of conventionally used information transfer rates (ITRs) and accuracies, the overall BCI system design should be more convenient, easy to use, and of course suitable for everyday use with a target population (people with disabilities). Many chapters build on enlarged versions of previously published papers, which are clearly arranged in a structured, sequential order, to offer the potential reader a comprehensive overview of this modern technology. As not all of the authors of original publications were involved in the preparation of this book, there are several discrepancies in the author lists, which are of course in agreement with all original authors. This book presents the major scientific findings of the BCI lab Kleve during the last years and can be considered to some extent to be a representation of the current state-of-the art in BCI systems based on the VEP activities. The first chapter of the book, "VEP-based Brain–Computer Interface Spellers: A Review", provides a short introduction into the BCI topic and an overview of the main application of most BCIs during the last decades, namely BCI spellers. The following four chapters presents our progress in the area of SSVEP-based processing. The second chapter, "Impact of the Number of Electrodes on BCI performance", analyses the typical number of EEG electrodes used in BCI applications, as smaller number of used EEG signal channels reduces the preparation time and simplifies the set-up and therefore, the possibilities for the practical use of the system. The next chapter, "Optimal Electrode Positions for an SSVEP-based BCI" presents the results from our very recent study and answers the question of "the specific locations of this reduced set of EEG electrodes" (if only several EEG electrodes are used, where to place them in order to achieve the highest BCI performance?). The following chapter, "Comparison of Different Visual Feedback Methods for SSVEP-based BCIs" presents one of our last BCI studies and analyses the influence of different visual feedback representations on the performance of BCI-based human-machine interaction. The last chapter in this section, "Age-related differences in SSVEP-based BCI performance" compares the BCI performances between participants from different age groups. The next two chapters of the book, "A Dictionary-Driven Spelling Application Based on cVEPs" and "User-friendly c-VEP based BCIs with Quintary m-Sequences" present the results from code-modulated VEPs, combined with a dictionary, to allow word prediction in order to increase the system performance alongside a novel way of cVEP stimulation. The next two sections of the book, "SSVEePy & MazeRunner – exploring BCI controlled VR games" and "Remote Driving of a Mobile Robotic Car Controlled by an SSVEP BCI in VR Environment", present our developments in the use of the BCI technology in a virtual reality (VR) environment and a typical way of improving the quality of BCI signals by removing the EEG artifacts. The last section of the book consists of three chapters with different practical BCI applications. Finally, I hope that the readers will enjoy reading the different chapters of this book.

Kleve, May 2020

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Project Coordinator of the projects ABCI, EBCI, BCI@HOME and M3S

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