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Brendan Z. Allison • Stephen Dunne
Robert Leeb • José del R. Millán
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Editors

Towards Practical Brain-Computer Interfaces

Bridging the Gap from Research to Real-World Applications

With 107 Figures

Springer

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Preface

Brain–computer interface (BCI) research is advancing rapidly. The last few years have seen a dramatic rise in journal publications, academic workshops and conferences, books, new products aimed at both healthy and disabled users, research funding from different sources, and media attention. This media attention has included both BCI fi (BCI-based science fiction) and stories in mainstream magazines and television news programs.

Despite this progress and attention, most people still do not use BCIs, or even know what they are. While the authors of this book generally have access to the best BCI equipment, and they know how to use it, the chapters are written in the old-fashioned way, with keyboards and mice instead of BCIs. This may be surprising because BCIs are generally presented inaccurately in the popular media, where undeserved hype and sloppy reporting often create a gap between expectations and reality.

This book aims to bridge that gap by educating readers about BCIs, with emphasis on making BCIs practical in real-world settings. Experts in BCI research widely agree that one of the major challenges in the field is moving BCIs from laboratory gadgets that work with some healthy users to tools that are reliable, straightforward, and useful in field settings for whoever needs them. Many of these experts discuss the state of the art and major challenges across four sections. Three of the sections address the three main components of BCIs: sensors, signals, and signal processing; devices and applications; and interfaces and environments. The last section summarizes other challenges that relate to complete BCI systems instead of one component.

BCI research is inherently interdisciplinary, requiring contributions from neuroscience, psychology, medicine, human–computer interaction (HCI), many facets of engineering, and other disciplines. Similarly, many sectors are involved in BCI research, including academia, small and large businesses, government, medicine, and different types of nonprofit institutions. The authors who contributed to this book represent an eclectic mix of these disciplines and sectors. This breadth of contributors provides different perspectives and should make this book relevant to a wide variety of readers.

However, while this book could be useful for different specialists in the BCI community, we also made a strong effort to keep the chapters practical and readable for people who do not have a background in BCI research or any related discipline. Chapters are written in plain English, without unnecessary technical detail, and acronyms and special terms are defined within chapters and in our glossary. Ample references are provided in case readers want more information. Hence, many readers outside of the conventional BCI community may enjoy this book for different reasons. Nurses, doctors, therapists, caretakers, and assistive technology practitioners may want to learn more about what real-world BCIs can (and cannot) do, which may help them decide whether a BCI is viable as an assistive technology. Other readers may instead be curious about BCIs for other user groups, including healthy users. Students might use this book to learn about BCIs, and teachers might assign chapters in relevant classes. Business experts and policy makers may want to learn more about whether BCIs are promising enough to merit additional funding through commercial investment or grants. Journalists, writers, or other people interested in developing articles, documentaries, or other shows might find helpful background information or inspiration here. Finally, we hope our book appeals to people who are just curious about a technology that has long captured the human imagination and could revolutionize how people interact with each other and their environments.

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Acronyms

AD	Assistive device
ANFIS	Adaptive neuro-fuzzy inference systems
ANOVA	ANalysis Of VAriance
AR	Augmented reality
ASSR	Auditory steady-state responses
AT	Assistive technology
BCI	Brain computer interface
BMI	Brain-machine interface
BNCI	Brain/neuronal computer interface
BSS	Blind source separation
CAD	Computer aided design
CLIS	Complete locked-in syndrome
CSP	Common spatial patterns
ECG	ElectroCardioGram
ECoG	ElectroCortic**o**Gram
EDA	ElectroDermal Activity
EEG	ElectroEncephaloGraphy
EM	Expectation maximization
EMG	ElectroMyoGram
EOG	ElectroOculoGraphy
ERD	Event related de-/synchronisation
ERP	Event-related potential
ERS	Event related de-/synchronisation
FES	Functional electrical stimulation
fNIRS	**f**unctional Near infrared spectroscopy
GMM	Gaussian mixture models
GSR	Galvanic skin response
hBCI	**h**ybrid BCI
HMM	Hidden Markov models
HR	Heart rate
ICA	Independent component analysis

ITR	Information transfer rate
KNN	K-nearest neighbors
LDA	Linear discriminant analysis
LED	Light emitting diode
LiS	Locked-in syndrome
LVQ	Linear vector quantization
MEG	MagnetoEncephaloGram
ME	Motor execution
MI	Motor imagery
MLP	Multi-layer perceptron
NIRS	Near InfraRed Spectroscopy
NN	Neural network
PCA	Principal component analysis
RESE	Random electrode selection ensemble
RLDA	Regularized linear discriminant analysis
SCI	Spinal cord injury
SFFS	Sequential floating forward search
SSSEP	Steady-state somatosensory evoked potential
SSVEP	Steady-state visual evoked potential
SVM	Support vector machine
UCD	User-centred design
VE	Virtual environment
VR	Virtual reality