

Contents

Part I User Guide

1	Brain–Computer Interfaces	3
1.1	Introduction	3
1.2	Brain–Computer Interfaces (BCIs)	3
1.3	Overview	6
	References	6
2	Brain Sensors and Signals	9
2.1	Relevant Sensors	9
2.2	Brain Signals and Features	10
2.2.1	Using Brain Signals for Communication	10
2.2.2	Mu/Beta Oscillations and Gamma Activity	12
2.2.3	The P300 Evoked Potential	14
2.3	Recording EEG	15
2.3.1	Introduction	15
2.3.2	Electrode Naming and Positioning	15
2.3.3	Important Brain Areas and Landmarks for BCIs	16
2.3.4	Placing Electrodes with a Cap	16
2.3.5	Removing Artifacts and Noise Sources	18
2.4	BCI Signal Processing	21
2.4.1	Introduction	21
2.4.2	Spatial Filtering	22
2.4.3	Feature Extraction: Sensorimotor Rhythms	26
2.4.4	Translation Algorithm	28
	References	29
3	Introducing BCI2000	37
3.1	Motivation	37
3.2	The Design of the BCI2000 Platform	38
3.2.1	A Common Model	38

- 3.2.2 Source Module and File Format 40
- 3.2.3 Signal Processing Module 41
- 3.2.4 User Application Module 41
- 3.2.5 Operator Module 41
- 3.2.6 System Variables 42
- 3.3 BCI2000 Advantages 43
- 3.4 System Requirements and Real-Time Processing 43
- 3.5 BCI2000 Implementations and Their Impact 44
- References 45

- 4 Tour of BCI2000 47**
- 4.1 Starting BCI2000 47
 - 4.1.1 Batch Files 47
 - 4.1.2 BCI2000 Launcher 48
- 4.2 Getting Help 48
- 4.3 Configuring BCI2000 49
 - 4.3.1 Module Settings 49
 - 4.3.2 Parameter Files 50
 - 4.3.3 Parameter Help 50
- 4.4 Important Parameters 51
- 4.5 Applying Parameters 51
- 4.6 Starting a Run 52
 - 4.6.1 Data Storage 53
- 4.7 Retrieving Data Offline 53
 - 4.7.1 Reviewing Brain Signals and Event Markers 53
 - 4.7.2 Viewing Parameters with BCI2000FileInfo 54
 - 4.7.3 Interactions with External Software 55
- 4.8 Overview of Additional Application Modules 55
 - 4.8.1 Stimulus Presentation 55
 - 4.8.2 P300 Speller 56
- 4.9 Where to Go from Here 57

- 5 User Tutorials 59**
- 5.1 General System Configuration 59
- 5.2 Virtual Cursor Movement with the Sensorimotor Rhythms 59
 - 5.2.1 Obtaining Sensorimotor Rhythm Parameters in an Initial Session 61
 - 5.2.2 Performing the Initial Sensorimotor Rhythm Session 62
 - 5.2.3 Analyzing the Initial Sensorimotor Rhythm Session 63
 - 5.2.4 Configuring Online Feedback 66
 - 5.2.5 Performing a Sensorimotor Rhythm Feedback Session 68
- 5.3 P300 BCI Tutorial 71
 - 5.3.1 General System Configuration 72
 - 5.3.2 Obtaining P300 Parameters in the Calibration Session 72
 - 5.3.3 Analyzing the Calibration Session with “Offline Analysis” 74

- 5.3.4 Performing a P300 Spelling Session 79
- References 80
- 6 Advanced Usage 83**
 - 6.1 Matlab MEX Interface 83
 - 6.1.1 Introduction 83
 - 6.1.2 Using BCI2000 MEX Files 83
 - 6.1.3 Building BCI2000 MEX Files 84
 - 6.1.4 BCI2000 MEX Functions 85
 - 6.2 Operator Scripting 87
 - 6.2.1 Events 87
 - 6.2.2 Scripting Commands 88
 - 6.2.3 Examples 88
 - 6.3 Command Line Options 89
 - 6.3.1 Operator Options 89
 - 6.3.2 Core Module Options 89
 - 6.3.3 Data File Formats 90
 - 6.4 AppConnector 92
 - 6.4.1 Introduction 92
 - 6.4.2 Scope 92
 - 6.4.3 Design 93
 - 6.4.4 Description 93
 - 6.4.5 Protocol 94
 - 6.4.6 Examples 94
 - 6.4.7 Parameterization from Within BCI2000 94
 - 6.4.8 Examples 95
 - 6.5 Expression Filter 96
 - References 97
- 7 Programming Reference 99**
 - 7.1 Building BCI2000 99
 - 7.1.1 Why Build from Source 99
 - 7.1.2 Tools Required 99
 - 7.1.3 How to Build 100
 - 7.1.4 Starting up BCI2000 101
 - 7.2 Writing a Custom Source Module 101
 - 7.2.1 Example Scenario 102
 - 7.2.2 Writing the ADC Header File 102
 - 7.2.3 ADC Implementation 103
 - 7.2.4 ADC Initialization 104
 - 7.2.5 Data Acquisition 105
 - 7.2.6 Adding the SourceFilter 106
 - 7.2.7 Finished 106
 - 7.3 Writing a Custom Signal Processing Module 106
 - 7.3.1 A Simple Low-Pass Filter 106
 - 7.3.2 The Filter Skeleton 107

7.3.3	The Process Function	107
7.3.4	The Initialize Member Function	108
7.3.5	The Preflight Function	109
7.3.6	Constructor and Destructor	110
7.3.7	Filter Instantiation	111
7.3.8	Visualizing Filter Output	111
7.4	Writing a Custom Matlab Filter	114
7.4.1	Online Algorithm Verification	114
7.4.2	An Example Algorithm in Matlab	114
7.4.3	Transforming Matlab Code into BCI2000 Events	115
8	Exercises	119
8.1	Source Module	119
8.2	Signal Processing Module	121
	References	125
9	Frequently Asked Questions	127
9.1	Timing Issues	127
9.2	Startup	127
9.3	Feedback	128
9.4	Replaying Recorded Data	128
9.5	Random Sequences	129
9.6	Visual Stimulation	129
	References	131

Part II Technical Reference

10	Core Modules	135
10.1	Operator	135
10.1.1	Starting BCI2000	135
10.1.2	Main Window	135
10.1.3	Parameter Configuration Window	138
10.1.4	Matrix Editor Window	140
10.1.5	Visualization Windows	140
10.2	Filter Chain	142
10.3	Data Acquisition Filters	143
10.3.1	DataIOFilter	144
10.3.2	AlignmentFilter	146
10.3.3	TransmissionFilter	147
10.3.4	SourceFilter	147
10.3.5	BCI2000FileWriter	148
10.3.6	EDFFileWriter	149
10.3.7	GDFFileWriter	149
10.3.8	NullFileWriter	151
10.4	Logging Input Filters	151
10.4.1	Input Logger	151

- 10.4.2 JoystickFilter (Obsolete) 152
- 10.4.3 KeyLogFilter (Obsolete) 153
- 10.4.4 MouseFilter (Obsolete) 154
- 10.5 Signal Source Modules 154
 - 10.5.1 SignalGeneratorADC 154
 - 10.5.2 gUSBampADC 156
 - 10.5.3 gMOBILabADC 159
 - 10.5.4 gMOBILabPlusADC 160
- 10.6 Signal Processing Filters 162
 - 10.6.1 SpatialFilter 162
 - 10.6.2 ARFilter 165
 - 10.6.3 FFTFilter 166
 - 10.6.4 P3TemporalFilter 168
 - 10.6.5 LinearClassifier 169
 - 10.6.6 Normalizer 172
- 10.7 Additional Signal Processing Filters 176
 - 10.7.1 LPFilter 176
 - 10.7.2 ConditionalIntegrator 176
 - 10.7.3 StateTransform 177
 - 10.7.4 ExpressionFilter 178
 - 10.7.5 MatlabFilter 179
- 10.8 Application Modules 180
 - 10.8.1 Cursor Task 180
 - 10.8.2 Stimulus Presentation 184
 - 10.8.3 P300 Speller 191
 - 10.8.4 Keystroke Filter 200
 - 10.8.5 Connector Filters 201
- 10.9 Tools 201
 - 10.9.1 BCI2000 Offline Analysis 201
 - 10.9.2 USBampGetInfo 205
 - 10.9.3 BCI2000FileInfo 206
 - 10.9.4 BCI2000Export 206
- 10.10 Localization 208
- 10.11 P300 Classifier 208
 - 10.11.1 Introduction 208
 - 10.11.2 Interface 209
 - 10.11.3 Reference 213
 - 10.11.4 Tutorial 215
 - 10.11.5 Example 216
- References 217
- 11 Contributed Modules 219**
 - 11.1 Source Modules 219
 - 11.1.1 Amp Server Pro 219
 - 11.1.2 BioRadio 221

- 11.1.3 BioSemi 2 221
- 11.1.4 Measurement Computing 222
- 11.1.5 Data Translation Boards 223
- 11.1.6 Micromed 225
- 11.1.7 Modular EEG 226
- 11.1.8 National Instruments 228
- 11.1.9 National Instruments MX 228
- 11.1.10 Neuroscan 229
- 11.1.11 BrainAmp Systems 231
- 11.1.12 Tucker-Davis Technologies 232
- 11.1.13 TMS Refa and Porti Systems 233
- 11.1.14 BrainProducts V-Amp 234
- 11.2 Tools 237
 - 11.2.1 EEGLabImport 237
- Appendix A The `USBampGetInfo` Command Line Tool 249**
- Appendix B The `neurogetparams` Command Line Tool 253**
- Index 255**



<http://www.springer.com/978-1-84996-091-5>

A Practical Guide to Brain-Computer Interfacing with
BCI2000

General-Purpose Software for Brain-Computer Interface
Research, Data Acquisition, Stimulus Presentation, and
Brain Monitoring

Schalk, G.; Mellinger, J.

2010, XXIII, 260 p., Hardcover

ISBN: 978-1-84996-091-5