

University of Groningen

Multichannel EEG Visualization

Caat, Michael ten

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version

Publisher's PDF, also known as Version of record

Publication date:

2008

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

Caat, M. T. (2008). *Multichannel EEG Visualization*. s.n.

Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

The publication may also be distributed here under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license. More information can be found on the University of Groningen website: <https://www.rug.nl/library/open-access/self-archiving-pure/taverne-amendment>.

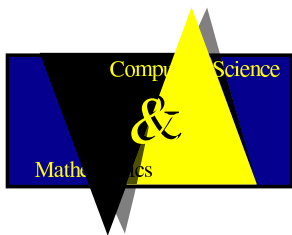
Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.

Multichannel EEG Visualization

Michael ten Caat



This research has been conducted within the Institute of Mathematics and Computing Science (IWI) and the School of Behavioral and Cognitive Neuroscience (BCN).

Cover: Conventional EEG representation (top left), EEG coherence graph (top right), tiled parallel coordinate map (bottom left), functional unit map (bottom right).

Caat, M., ten

Multichannel EEG Visualization

Michael ten Caat

Thesis Rijksuniversiteit Groningen. - With index, ref.

ISBN 978-90-367-3326-7

Online version:

ISBN 978-90-367-3334-2

RIJKSUNIVERSITEIT GRONINGEN

Multichannel EEG Visualization

Proefschrift

ter verkrijging van het doctoraat in de
Wiskunde en Natuurwetenschappen
aan de Rijksuniversiteit Groningen
op gezag van de
Rector Magnificus, dr. F. Zwarts,
in het openbaar te verdedigen op
vrijdag 1 februari 2008
om 16.15 uur

door

Michael ten Caat
geboren op 23 september 1979
te Coevorden

Promotores: Prof. dr. J. B. T. M. Roerdink
Prof. dr. ir. N. M. Maurits

Beoordelingscommissie: Prof. dr. ir. B. Preim
Prof. dr. ir. J. J. van Wijk
Prof. dr. R. de Jong

ISBN: 978-90-367-3326-7

Contents

1	Introduction	1
1.1	Electroencephalography (EEG)	3
1.1.1	Brain Potentials	3
1.1.2	Anatomical References	4
1.1.3	EEG Recording	5
1.1.4	Rhythms	7
1.1.5	Event-Related and Evoked Potentials	7
1.1.6	EEG Analysis	9
1.2	Visualization	11
1.2.1	Multivariate and Time-Varying Data	11
1.2.2	Relational Data: Graphs	15
1.3	Thesis Contribution & Organization	16
2	Tiled Parallel Coordinates for Time-Varying Multichannel EEG Data	17
2.1	Introduction	17
2.2	EEG Data	18
2.2.1	Characteristics	18
2.2.2	Somatosensory Evoked Potential (SEP) Data	19
2.3	Existing EEG Visualization Methods	19
2.3.1	Conventional EEG Representation	19
2.3.2	Butterfly Plot	20
2.3.3	Topographic Layout	20
2.3.4	EP Image	21
2.4	Tiled Parallel Coordinates for Multichannel EEG Data	22
2.4.1	Review of the Parallel Coordinate Method	22
2.4.2	Tile Design	24
2.4.3	Tiled Parallel Coordinates	26
2.5	Qualitative Evaluation	28
2.6	User Evaluation	29
2.6.1	Goal	30
2.6.2	Participants	30
2.6.3	Data	30
2.6.4	Task	31

2.6.5	Measurements	31
2.6.6	Subjective Evaluation	32
2.6.7	Results	32
2.7	Discussion	36
3	Data-Driven Visualization of Multichannel EEG Coherence with Functional Units	39
3.1	Introduction	40
3.2	EEG Coherence	41
3.3	Related Work	42
3.3.1	EEG and MEG	43
3.3.2	fMRI	44
3.3.3	Conclusion	45
3.4	Data Representation	45
3.4.1	Experimental Setup	45
3.4.2	EEG Coherence Graph	46
3.5	FU Detection	46
3.5.1	Maximal Clique Based (MCB) Method	46
3.5.2	Watershed Based (WB) Method	50
3.5.3	Improved Watershed Based (IWB) Method	51
3.6	FU Visualization	53
3.6.1	FU Map for Individual Dataset Analysis	53
3.6.2	Data-Driven Group Analysis	55
3.7	Results	55
3.7.1	FU Map	56
3.7.2	Group Analysis	58
3.7.3	Threshold Effect	65
3.8	Discussion and Conclusions	66
4	EEG Coherence Analysis Using Functional Units Applied To Mental Fatigue	69
4.1	Introduction	69
4.2	Methods	71
4.2.1	Participants and Task	71
4.2.2	EEG Coherence	72
4.2.3	Individual Analysis: Functional Unit (FU) Map	73
4.2.4	Group Analyses: Group Mean Coherence Map and Group FU Size Map	74
4.3	Results	75
4.3.1	Individual Analysis: FU Map	76
4.3.2	Group Analyses: Group Mean Coherence Map and Group FU Size Map	78
4.4	Discussion and Conclusions	80
5	Discussion	83
5.1	Summary & Conclusions	83
5.2	Perspectives	85

Bibliography	87
Index	97
Publications	103
Samenvatting	105
Dankwoord	111

