Preface

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetuer id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

Abstract

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. In hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

Samenvatting

Fusce mauris. Vestibulum luctus nibh at lectus. Sed bibendum, nulla a faucibus semper, leo velit ultricies tellus, ac venenatis arcu wisi vel nisl. Vestibulum diam. Aliquam pellentesque, augue quis sagittis posuere, turpis lacus congue quam, in hendrerit risus eros eget felis. Maecenas eget erat in sapien mattis porttitor. Vestibulum porttitor. Nulla facilisi. Sed a turpis eu lacus commodo facilisis. Morbi fringilla, wisi in dignissim interdum, justo lectus sagittis dui, et vehicula libero dui cursus dui. Mauris tempor ligula sed lacus. Duis cursus enim ut augue. Cras ac magna. Cras nulla. Nulla egestas. Curabitur a leo. Quisque egestas wisi eget nunc. Nam feugiat lacus vel est. Curabitur consectetuer.

Suspendisse vel felis. Ut lorem lorem, interdum eu, tincidunt sit amet, laoreet vitae, arcu. Aenean faucibus pede eu ante. Praesent enim elit, rutrum at, molestie non, nonummy vel, nisl. Ut lectus eros, malesuada sit amet, fermentum eu, sodales cursus, magna. Donec eu purus. Quisque vehicula, urna sed ultricies auctor, pede lorem egestas dui, et convallis elit erat sed nulla. Donec luctus. Curabitur et nunc. Aliquam dolor odio, commodo pretium, ultricies non, pharetra in, velit. Integer arcu est, nonummy in, fermentum faucibus, egestas vel, odio.

Sed commodo posuere pede. Mauris ut est. Ut quis purus. Sed ac odio. Sed vehicula hendrerit sem. Duis non odio. Morbi ut dui. Sed accumsan risus eget odio. In hac habitasse platea dictumst. Pellentesque non elit. Fusce sed justo eu urna porta tincidunt. Mauris felis odio, sollicitudin sed, volutpat a, ornare ac, erat. Morbi quis dolor. Donec pellentesque, erat ac sagittis semper, nunc dui lobortis purus, quis congue purus metus ultricies tellus. Proin et quam. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Praesent sapien turpis, fermentum vel, eleifend faucibus, vehicula eu, lacus.

Contents

Preface **i**

Abstract **ii**

Samenvatting **iii**

I Introduction & Literature **1**

1 Brain-Computer Interfaces **2**
1.1 Rationale 2
1.2 Overview & state-of-the-art 2
1.3 Visual Event-Related Potential based BCIs 2

2 Linear ERP decoding **3**
2.1 LCMV-beamforming 3
2.2 Toeplitz-LDA 3
2.3 Other methods 3

3 Gaze-independent BCIs **4**
3.1 Oculomotor deficits in Locked-in Syndrome 4
3.2 Gaze-independent visual BCIs 4
3.3 Benefits & drawbacks of covert attention in BCI operation . . 4
3.4 Electrophysiological correlates of covert attention 4
3.5 Compensating for covert attention 4

4 Problem statement & rationale **5**

II Algorithms & Decoders **6**

5 Kronecker-structured discriminant analysis **7**
5.1 The spatiotemporal EEG covariance 7
5.2 The single-KP covariance model 7
5.3 The sum-of-KP covariance model 7
5.4 Decoding performance 7
5.5 Extension into the space-time-frequency domain 7

6 Tensor discriminant analysis **8**
6.1 The tensor structure of EEG data 8
6.2 Higher-order Discriminant Analysis 8
6.3 Block-term Tensor Discriminant Analysis 8
6.4 Decoding performance 8
6.5 Tensorizations coping with latency jitter 8

7 Woody Classifier-based Latency Estimation **9**
7.1 The role of jitter in gaze-independent ERP decoding 9
7.2 Latency estimation and correction 9
7.3 Classifier-based Latency Estimation 9
7.4 Classifier-based Latency Estimation with Woody iterations . 9
7.5 Simulation study 9

III Experiments & Applications **10**

8 Interface design & experimental setup **11**
8.1 The Hex-o-Spell interface 11
8.2 Visuospatial attention conditions 11

9 Compensating jitter for gaze-independent decoding **12**
9.1 Data collection & preprocessing 12
9.2 Results 12
9.3 Discussion 12

10 Patient cases **13**
10.1 Patient presentation 13
10.2 Data collection & preprocessing 13
10.3 Outcomes 13
10.4 Discussion 13

11 Integrating gaze-tracking data **14**

12 Conclusions & recommendations **15**
12.1 General discussion 15
12.2 Limitations 15
12.3 Future directions 15
12.4 Working with patients 15
12.5 Conclusion 15

Curriculum vitae **16**

Publications **17**

Funding & acknowledgments **18**

Personal contribution **19**

Conflict of interest **20**

List of Figures

List of Tables

Part I

Introduction & Literature

Chapter 1

Brain-Computer Interfaces

1.1 Rationale

1.2 Overview & state-of-the-art

different recording technologies and level of invasiveness + infographic active/reactive/passive + infographic

1.3 Visual Event-Related Potential based BCIs

chapters don't nicely follow imrad structure. Is this problem?

concern: is a bit in between formula 1 and formula 2

Check provisionary and final doctoral plan for motivation

Chapter 2

Linear ERP decoding

2.1 LCMV-beamforming

proof equivalent to LDA

2.2 Toeplitz-LDA

2.3 Other methods

Chapter 3

Gaze-independent BCIs

3.1 Oculomotor deficits in Locked-in Syndrome

3.2 Gaze-independent visual BCIs

3.3 Benefits & drawbacks of covert attention in BCI operation

3.4 Electrophysiological correlates of covert attention

3.5 Compensating for covert attention

Chapter 4

Problem statement & rationale

Goal: Enable communication for eye-motor impaired patients

Method: Design a comfortable interface that allows them to maximally exploit their residual gaze capabilities, by leveraging a non-invasive high-ITR visuospatial ERP-based BCI and improving ERP decoding performance (in general and specifically in gaze-independent settings).

Novelty:

Part II

Algorithms & Decoders

Chapter 5

Kronecker-structured discriminant analysis

check chapters/structure paper

check structure Leuven.ai poster

5.1 The spatiotemporal EEG covariance

5.2 The single-KP covariance model

5.3 The sum-of-KP covariance model

5.4 Decoding performance

5.5 Extension into the space-time-frequency domain

Chapter 6

Tensor discriminant analysis

6.1 The tensor structure of EEG data

6.2 Higher-order Discriminant Analysis

6.3 Block-term Tensor Discriminant Analysis

6.4 Decoding performance

6.5 Tensorizations coping with latency jitter

Chapter 7

Woody Classifier-based Latency Estimation

7.1 The role of jitter in gaze-independent ERP decoding

7.2 Latency estimation and correction

7.3 Classifier-based Latency Estimation

7.4 Classifier-based Latency Estimation with Woody iterations

7.5 Simulation study

check earlier draft alignment paper

check deleted paragraphs in jitter paper

Part III

Experiments & Applications

Chapter 8

Interface design & experimental setup

8.1 The Hex-o-Spell interface

8.2 Visuospatial attention conditions

Chapter 9

Compensating jitter for gaze-independent decoding

9.1 Data collection & preprocessing

9.2 Results

9.3 Discussion

check chapters paper

Chapter 10

Patient cases

10.1 Patient presentation

10.2 Data collection & preprocessing

10.3 Outcomes

10.4 Discussion

Define structure patient results/discussion

Chapter 11

Integrating gaze-tracking data

Chapter 12

Conclusions & recommendations

12.1 General discussion

12.2 Limitations

12.3 Future directions

12.4 Working with patients

12.5 Conclusion

Curriculum vitae

Publications

Funding & acknowledgments

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetuer id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

Personal contribution

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Conflict of interest

The authors declare no conflict of interest.