MASTER THESIS

Should you make the Explicit-duration Hidden Markov model your asset when analysing intensive longitudinal data for behavioural research?

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ARTICLE HISTORY

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ABSTRACT

This template is for authors who are preparing a manuscript for a Taylor & Francis journal using the LaTeX document preparation system and the `interact` class file, which is available via selected journals' home pages on the Taylor & Francis website.

KEYWORDS

Sections; lists; figures; tables; mathematics; fonts; references; appendices

1. Introduction

- We want to both diagnose the disorder based on pattern and also see how dynamics evolve over time.
- It is now generally believed that individuals transition in and out of different brain states during the course of the scanning session.Thus, there is a need to estimate the timing of the transitions between states, as well as the structure of the states themselves
- the EMA has been highly advise to study the evolving disorder or humane behaviour phenomena closely.

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- Ater a thorough research in the disorders we suspect that data might be generated via something resembling hidden semi markov model.
- the method advice by Ellen is mhmm
- the HMM is increasingly adopted since it provides a convenient way of formulating an extension of a mixture model McLachlan and Peel (2000) to allow for dependent data. How? In mixture model we would assume that the observations of dependent variables are independently derived from a given distribution but with mhmm we consider data that could be differently generated
- HMMs [16] are a natural modelling approach to take, given that we have an observable sequence from a system in which it is not unreasonable to believe that the hidden states may be governed by a Markov process. They have been widely studied in statistics [17] and have been applied extensively in many applications, such as in speech recognition and biological sequence analysis [18, 19].
- the framework is able to handle large amounts of data to infer the network states, as well as the other model parameters such as the probabilities of transitioning between states. Moreover, these states and parameters can be estimated in a relatively computationally inexpensive manner. Second, while network states are estimated at the group level, individuality is respected in that information about when a state becomes active is subject-specific. Therefore, we are still able to obtain subject-specific estimates of an individual's state sequence and the amount of time he/she spends in each state. Third, the method is likelihood based, leaving room for model selection techniques to be employed when deciding upon the number of states to be estimated, as well as the number of brain regions to be included in the analysis. Fourth, the model is able to capture quick changes in brain connectivity, unlike the sliding window based approach.
- Shappell, Caffo, Pekar, and Lindquist (2019) Some studies revealing that while both the HMM and HSMM are able to identify quick state switches with similar accuracy, the HSMM is superior to the HMM in regard to estimating sojourn times with fewer switches. This suggests that the HSMM is a more flexible model and the better model choice when estimating sojourn times and subject state sequences for data where subjects aren't expected to switch states at a rapid

rate.

- There are 3 options we can fit the hmm:
  (1) on a pooled data not taking into consideration the multilevel structure of the participants
  (2) we can apply mixture hidden Markov models to the data which doesnt give us a chance to refer the individual patients dynamics to the group level estimates
  (3) we can apply the mhmm that takes into account both the homogeneity of observations between subjects and heterogeneity of individuals while treating it all as the same system.

2. Hidden Markov model family

In this section I will present a brief introduction to HMM and HSMM followed by how they can be extended to a multilevel framework. I will take a moment to explain why the Bayesian statistics is an appropriate framework to evaluate the MHMM and MHSMM.

2.1. Hidden Markov models

2.2. Explicit-Duration Hidden Markov Model

2.3. HMM and HSMM(ED-HMM) in multilevel framework

2.4. Bayesian estimation

3. Methods

The simulations study is constructed to compare the performance of MHSMM and MHMM. We target to inspect the state duration estimation, latent state sequence estimations and precisions of transitions matrix and emission distributions parameters. To accomplish the task, we aim to vary mean state duration, number of hidden states and number of observations within individuals.

3.1. Simulation Study: Data generating

3.2. Model Fitting

3.3. Model Evaluation

3.4. Real-life application

4. Results

Results.

Acknowledgement(s)

An unnumbered section, e.g. `\section*{Acknowledgements}`, may be used for thanks, etc. if required and included *in the non-anonymous version* before any Notes or References.

Disclosure statement

An unnumbered section, e.g. `\section*{Disclosure statement}`, may be used to declare any potential conflict of interest and included *in the non-anonymous version* before any Notes or References, after any Acknowledgements and before any Funding information.

Funding

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Nomenclature/Notation

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References

McLachlan, G., & Peel, D. (2000). *Finite mixture models: Mclachlan/finite mixture models.* Hoboken, NJ, USA. Retrieved from `http://doi.wiley.com/10.1002/0471721182`

Shappell, H., Caffo, B. S., Pekar, J. J., & Lindquist, M. A. (2019, May). Improved state change estimation in dynamic functional connectivity using hidden semi-markov models. *NeuroImage*, *191*, 243–257. Retrieved from `https://linkinghub.elsevier.com/retrieve/pii/S1053811919300990`

5. Appendices

Appendix A. Troubleshooting

Authors may occasionally encounter problems with the preparation of a manuscript using LaTeX. The appropriate action to take will depend on the nature of the problem:

(i) If the problem is with LaTeX itself, rather than with the actual macros, please consult an appropriate LaTeX 2_ε manual for initial advice. If the solution cannot be found, or if you suspect that the problem does lie with the macros, then please contact Taylor & Francis for assistance (`latex.helpdesk@tandf.co.uk`), clearly stating the title of the journal to which you are submitting.

(ii) Problems with page make-up (e.g. occasional overlong lines of text; figures or tables appearing out of order): please do not try to fix these using 'hard' page make-up commands – the typesetter will deal with such problems. (You may, if you wish, draw attention to particular problems when submitting the final version of your manuscript.)

(iii) If a required font is not available on your system, allow TeX to substitute the font and specify which font is required in a covering letter accompanying your

files.

Appendix B. Obtaining the template and class file

B.1. Via the Taylor & Francis website

This article template and the `interact` class file may be obtained via the 'Instructions for Authors' pages of selected Taylor & Francis journals.

Please note that the class file calls up the open-source LaTeX packages booktabs.sty, epsfig.sty and rotating.sty, which will, for convenience, unpack with the downloaded template and class file. The template optionally calls for natbib.sty and subfig.sty, which are also supplied for convenience.

B.2. Via e-mail

This article template, the `interact` class file and the associated open-source LaTeX packages are also available via e-mail. Requests should be addressed to `latex.helpdesk@tandf.co.uk`, clearly stating for which journal you require the template and class file.