Accepted Manuscript

Neural mass model-based tracking of anesthetic brain states

Levin Kuhlmann, Dean R. Freestone, Jonathan H. Manton, Bjorn Heyse, Hugo E.M. Vereecke, Tarmo Lipping, Michel M.R.F. Struys, David T.J. Liley

PII: S1053-8119(16)00244-5
DOI: doi: 10.1016/j.neuroimage.2016.03.039
Reference: YNIMG 13044

To appear in: *NeuroImage*

Received date: 23 November 2015
Accepted date: 18 March 2016

Please cite this article as: Kuhlmann, Levin, Freestone, Dean R., Manton, Jonathan H., Heyse, Bjorn, Vereecke, Hugo E.M., Lipping, Tarmo, Struys, Michel M.R.F., Liley, David T.J., Neural mass model-based tracking of anesthetic brain states, *NeuroImage* (2016), doi: 10.1016/j.neuroimage.2016.03.039

Neural mass model-based tracking of anesthetic brain states

Levin Kuhlmann[a,*], Dean R. Freestone[b], Jonathan H. Manton[a], Bjorn Heyse[c], Hugo E.M. Vereecke[d], Tarmo Lipping[e], Michel M.R.F. Struys[c,d], and David T.J. Liley[g,f]

[a] *Department of Electrical and Electronic Engineering, University of Melbourne, Parkville VIC 3010, Australia.*

[b] *Department of Medicine - St. Vincent's, University of Melbourne, Parkville VIC 3010, Australia.*

[c] *Department of Anesthesia, Ghent University Hospital, Gent, Belgium*

[d] *Department of Anesthesiology, University of Groningen, University Medical Center Groningen, The Netherlands*

[e] *Department of Information Technology, Pori Campus, Tampere University of Technology, Pori, Finland.*

[f] *Cortical Dynamics Ltd, North Perth, WA, Australia.*

[g] *Brain and Psychological Sciences Research Centre, Swinburne University of Technology, Hawthorn, VIC, Australia.*

Abstract

Neural mass model-based tracking of brain states from electroencephalographic signals holds the promise of simultaneously tracking brain states while inferring underlying physiological changes in various neuroscientific and clinical applications. Here, neural mass model-based tracking of brain states using the unscented Kalman filter applied to estimate parameters of the Jansen-Rit cortical population model is evaluated through the application of propofol-based anesthetic state monitoring. In particular, 15 subjects underwent propofol anesthesia induction from awake to anesthetised while behavioural responsiveness was monitored and frontal electroencephalographic signals were recorded. The unscented Kalman filter Jansen-Rit model approach applied to frontal electroencephalography achieved reasonable testing performance for classification of the anesthetic brain state (sensitivity: 0.51; chance sensitivity: 0.17; nearest neighbor sensitivity 0.75) when compared to approaches based on linear (autoregressive moving average) modelling (sensitivity 0.58; nearest neighbor sensitivity: 0.91) and a high performing standard depth of anesthesia monitoring measure, Higuchi Fractal Dimension (sensitivity: 0.50; nearest neighbor sensitivity: 0.88). Moreover, it was found that the unscented Kalman filter based parameter estimates of the inhibitory postsynaptic potential amplitude varied in the physiologically expected direction with increases in propofol concentration, while the estimates of the inhibitory postsynaptic potential rate constant did not. These results combined with analysis of monotonicity of parameter estimates, error analysis of parameter estimates, and observability analysis of the Jansen-Rit model, along with considerations of extensions of the Jansen-Rit model, suggests that the Jansen-Rit model combined with unscented Kalman filtering provides a valuable reference point for future real-time brain state tracking studies. This is especially true for studies of more complex, but still computationally efficient, neural models of anesthesia that can more accurately track the anesthetic brain state, while simultaneously inferring underlying physiological changes that can potentially provide useful clinical information.

*Corresponding author at: Department of Electrical and Electronic Engineering, The University of Melbourne, Parkville VIC 3010, Australia. E-mail address: levink@unimelb.edu.au (L. Kuhlmann)