16.1.

The Review of the doctoral thesis "Dynamic system identification methods for fMRI data processing" by Ing. Jana Nováková

Curentness topic

The submitted doctoral thesis is oriented to biomedical research area, namely to functional Magnetic Resonance Imaging (fMRI). The fMRI is a non-invasive technique for studying the brain activity. Since the early 1990s, it has gained growing popularity in both clinical and basic neuroscience research fields. The field that has grown around the acquisition and analysis of fMRI data is interdisciplinary in nature and involves contributions from researchers in neuroscience, psychology, physics and statistics among others. Various statistical methods have been proposed for the analysis of fMRI data. The methods can be categorized into two complementary groups, model-driven and data-driven. Model-driven approaches include statistical parametric mapping (SPM), which is a very popular fMRI analyzer, and a variety of Bayesian techniques. Data-driven approaches consist of cluster analysis, principal component analysis and independent component analysis (ICA). There are also comparison studies of the fMRI methods. Although some procedures outperform others in certain contexts, it seems that no globally optimal procedure is known. Therefore, the fRMI data processing is undoubtedly a current topic for improving medical diagnostics and for neuroscience.

The aims of the thesis

1. Give a comprehensive review of techniques and procedures used in the fMRI area from the system identification viewpoint.
2. Get familiar with the state of the art of techniques used in fMRI data processing, namely with Dynamic Causal Modelling (DCM), establish partnership with the Department of Neurology, Charles University.

3. Develop alternatives to fNRI data processing procedures, namely to the DCM, based on system identification. Demonstrate them with simulated and experimental MRI data.

The structure and content

The Ph.D. thesis consists of seven chapters and 69 pages. It is written in English. Section 1 is focused on motivation, outline of the thesis aspects and state of the art of the fMRI data processing, (8 pages). The specific goals are given in Section 2, (1 page). The overview concerning the fMRI principles, signals and features is presented in Section 3 (7 pages). Section 4 introduces and describes a toolbox for Statistical Parametric Mapping for functional neuroimaging toolbox (SPM toolbox), which was developed at the Institute of Neurology,

University College London (10 pages). Section 5 contains a description of the Writer`s cramp study-project of the Department of the Neurology, Charles University (10 pages). The results of the project were published in a short paper in NeuroEndocrinology Letters and Ing. Nováková was one of the 9 coauthors of the paper. Probably the most important Section 6 considering the above mentioned aims of the thesis deals with an application of a well known subspace identification method from Matlab System Identification Toolbox (20 pages). Eventually, in Section 7, the author of the thesis expressed her opinion on how the aims were fulfilled and she presented suggestions for future research (3 pages).

Quality of the PhD thesis

a) The choice of the thesis aims is somewhat questionable. The first and second aims represent just sort of obligation but do not constitute research progress. The third one is aimed in principle on "developing alternatives to fNRI data processing procedures" and the alternative comes out of subspace identification. This is definitely a topic that could be considered interesting from the perspective of control engineering. But only an application of the standard subspace identification method in fRMI was performed. However, it is not clear how the application contributes to theoretical development in the field of Control Engineering and Robotics (the fields of study of Ing. Nováková).
b) More explanation is needed in the first and third sections for readers to convince them that the first goal is fulfilled and why a relatively trivial application of one subspace identification method is sufficient for a PhD thesis. This statement is also supported by the author of the thesis because in the subsection "Suggestions for future research" she proposes to use and test other parameter identification methods based on ARX or OE models. Why not. In my opinion, other parameter optimization identification techniques can also be used such as prediction error methods, maximum likelihood methods or instrumental variable methods. But all this should have been done in this thesis

c) The SPM toolbox description should be more detailed, but could rather be presented in Appendix

d) Description of the Writer`s cramp study-project of the Department of the Neurology, Charles University can be introduced in the thesis, however many other researchers worked in the biomedical project and the role and contribution of the author to the project is not specified. Is there a part of the project which represents theoretical development in the field of Control Engineering and Robotics?

e) As far as the third aim is concerned, indeed, the Subspace Identification Methods (SIM) offer an alternative to input-output parameter identification methods due to simple and general parametrization for MIMO systems. Most SIMs fall into the unifying theorem proposed by van Overschee and de Moor (1995), among which

belong the Canonical Variate Analysis by Larimore (CVA) (1990), the N4SID (1994), the subspace splitting (1996), and the Multivariate Output Error State sPace (MOESP) (1992). However, the author only applied the Subspace State Space System Identification (N4SID) method from Matlab System Identification Toolbox in Section 6. Description and performance of these methods, their analysis, justification for selection of one of them (N4SID) or their further development, none of this is presented in the thesis. Extensive simulation experiments, thorough discussion of the results, interpretation of the obtained models, real effects to medical diagnostics and a theoretical analysis are missing as well.

In addition to the above mentioned substantive objections I have a few minor notes e.g., in Subsection 6.2.1, equation (6.1), (6.2) are not equations, several pages are empty e.g. 10, 18, description of figures and tables is often insufficient, the relation of nonlinear models in Introduction and in the following sections is not discussed, description of the state of art is superficial.

With respect to previous text concerning quality of the submitted thesis, I am inclined to consider the submitted thesis as a technical report for the state examination in Ph.D study rather than as a doctoral thesis. It is difficult to find which part of the thesis represents new results for the Control Engineering and Robotics field. Perhaps, Subsection 6.3 introduces an idea how to design brain system structure using a bilinear state space model. Nevertheless, that would have to have been significantly elaborated. Generally speaking, importance for the development of Control Engineering and Robotics is questionable. Significance for biomedical research is for me difficult to evaluate, even knowing that Ing. Nováková with coworkers published results of experiments using the N4SIM in biomedical journals and conferences.

Conclusion

The quality of the manuscripts corresponds rather to a technical report for the state examination in Ph.D study than to a doctoral thesis. Theoretical contribution to study fields "Control Engineering and Robotics" is not obvious.

Despite my negative opinion, I recommend the thesis for the defense, to enable discussion of the results of the thesis by all members of the committee.

Pilsen, May 3, 2013

Prof. Ing. Miroslav Šimandl, CSc.

Department of Cybernetics, Faculty of Applied Sciences

University of West Bohemia