16. 9.

Review of the Doctoral Dissertation Thesis

Dynamic system identification methods for fMRI data processing

submitted by

Ing. Jana Nováková

1. ***Is the treated topic up to date?***

Understanding how the human brain functions, what principles it applies as well as the reasons for its failures observed e.g. in neurology, is one of the greatest challenges of current research. Scientists approach these tasks equipped by various sophisticated technological means that allow parallel collection of numerous signals produced during different forms of brain activities. Most often, these signals represent highly aggregated cumulative information provided by all the neurons from a selected location. Finding proper interpretation for such signals is far from straightforward and it is necessary to search for specific novel methods that can help in answering questions concerning e.g. cognitive processes characterized by strong interaction between various brain regions. Identification of interaction between diverse brain regions from fMRI data is the main topic of the thesis. The goals of the dissertation are clearly stated in the Chapter 2 at page 9. They begin by a thorough state of the art review searching for ideas that could support design and development of an alternative (or a complement) to dynamic causal modelling – a method currently considered to be a "classical" approach to processing data resulting from fMRI. This topic is certainly highly up-to-date.

2. ***What methods have been selected?***

First, the author applied dynamic causal modelling (DCM) approach as a method for solving a complex task of evaluating real life data collected in writer's cramp study at the Department of Neurology of the 1st Faculty of Medicine of the Charles University. Her task has been to verify therapeutic impact of repetitive Transcranial Magnetic Stimulation (rTMS) therapy by comparing patient's function/abbility before and after treatment. Dynamic causal modelling assumes existence of a model that can be confronted with the data. But no such model has been available in advance for the considered problem. Consequently, it proved necessary to enumerate all possible models that meet the constraints resulting from domain knowledge first and to select from this list the model that fits best the considered experimental data later. This proved to be a very demanding exercise since 180 models had to be tested to prove positive impact of rTMS. All over this is an interesting result per se, the author decided to go further and to summarize the main drawbacks related to DCM. This reflection points to combinatorial complexity as to the main bottleneck of the applied process - the sections 5.3.3 and 5.3.4 (p.34-35) document why it was necessary to design and test so many models. The author suggests a reasonable way how to pass by this bottleneck: she comes up with a dynamic system identification method that can automatically design internal structure of the model. This highly ambitious goal is adressed in the Chapter 6.

The Chapter 6 represents the most innovative part of the thesis since the author takes full advantage of her background in control engineering and she applies it for the benefit of medical problem solution. Using methods that have been recently designed for analysis of complex technical systems, namely dynamic system identification and estimation, the author offers very efficient procedures how to estimate full connectivity of any DCM.

Computationally useful reduced models can be obtained from this complex model in the next phase. All the suggested procedures are implemented and tested on simulated fMRI data with very promising results reviewed in the section 6.3.3 (p.59). The used methods are appropriate and they have been very well selected. The text reflects deep knowledge of relevant recent references.

The thesis treats a true interdisciplinary problem and hopefully it will be studied both by technicians and by professionals with medical background. That is why it would be useful to be very careful in its presentation – I would certainly recommend to provide the list of abbreviations (e.g. BOLD, MIMO, ..) and to explain in more detail some used basic notions or procedures including the pre-processing mentioned on p. 22.

3. ***Did the thesis succeed to achieve its goal?***

The thesis proves that brain research can benefit from the recent developments in control engineering, namely in the field of dynamic system identification methods. The suggested ideas are implemented, their results and properties are clearly documented through extensive well-designed simulation experiments. The thesis did certainly accomplish its goals and intentions.

It would be most interesting to apply the novel approach suggested in the Chapter 6 to real life data treated in the Chapter 5 and to compare the results obtained by both approaches. Is this planned or is there some methodological reason why this cannot be done?

4. ***Evaluation of the presented results and their originality***

The thesis presents results of high quality and originality that have been published in three papers in journals with impact factor above 1. Ing. Novakova is a co-author of all these papers. Importance of her contribution is stressed by the fact that she is the first author of one of them.

5. ***What are the merits for practical applications and for further advance of science?***

The methodology suggested in the thesis enhances possibilities for identification of intrinsic brain structures and sheds thus a new light on studies related to cognitive processes. That is why it can be expected that the suggested approach will be reused in number of other applications that work with fMRI data.

6. ***Can the thesis be classified as an original creative research of its author? Does it include new scientific results published by the author?***

The submitted thesis describes original creative research of its author and it presents valuable scientific results. The chosen topic is systematically treated and it builds on extensive amount of preliminary knowledge described in the cited literature. The thesis meets all the expected requirements and *I recommend accepting this thesis for the defence procedure*.

Prague, 9th September 2013

Prof. RNDr. Olga Štěpánková, CSc.
K 333, FEL ČVUT