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Review of the thesis work

## Mohamed Fawzy Ibrahim Issa: Novel Methods for Removing EEG Artifacts and Calculating Dynamic Brain Connectivity

Improving the signal-to-noise ratio of EEG signals is an important and extensively researched field. The complexity of the brain as well as the parameters of the EEG signal make difficult the removal of different artifacts. A number of methods are available for this purpose. The general problem is that the improvement of the signal-to-noise ratio also causes the distortion of the signal. The thesis work gives an evaluation of the most popular methods and suggests a new combination to cancel artifact caused by eye movement (EOG) and cardiac activity (ECG). These artifacts cannot be avoided during examinations requiring EEG recording and they often significantly contaminate the EEG signal.

The effective rehabilitation of stroke patients requires the objective assessment of patients' actual state. The conventional procedure is based on imaging technologies, mostly CT and MRI. These technologies have excellent spatial resolution but their temporal resolution is weak. It is a major disadvantage when the dynamic properties of the brain is concerned. The thesis work suggests the *brain connectivity measure* as a new parameter to characterize the actual state of a stroke patient in the course of rehabilitation. The assessment of brain connectivity does not require expensive equipment while the test is simple and safe for the patients. However, introduction of the method into healthcare requires further research work involving much more patients, and also medical doctors.

The thesis work is 121 pages long. It is divided into five main chapters (EEG artifacts and literature review, Removal of EOG artifacts, Removal of cardiac ECG artifacts, Functional connectivity in ischemic stroke and Increasing the temporal resolution of dynamic functional connectivity with EEMD) plus four short ones (Introduction, Introduction to EEG signal processing, Conclusions and Summary phrasing the four theses). The 235 cited references are relevant.

In response to my review completed for the faculty debate the author elaborated an 8-page detailed reaction. The majority of the reactions are sound and acceptable. Some of his reactions were inserted into the final version of the thesis work and some were not. In my review I bring up the most important questions even if these were answered but not embedded into the thesis work.

The four theses concentrate on the most important results of the author. *These are backed by reviewed publications* (those describing thesis I and II in journals with IF) *and attest the author's ability for scientific research.*

The described research work substantiates the theses, which can mainly be accepted as new scientific achievement. Thesis III is a proposal for brain functional connectivity metrics to monitor and quantify stroke patient recovery. Proposing metrics is less than expected from a scientific thesis. To prove the optimality of the proposed metrics requires clinical tests. The number of tested persons (patients as well as healthy control subjects) is relatively low. I agree with the author, *'further work on a larger patient population is needed for statistically significant results'.*

The proposed EOG removal algorithm is summarized in Figure 4-1. The flow-chart and the related explanation do not exactly define the algorithm. In the flow-chart, following EOG peak detection either the component is rejected or the peak is corrected. The decision is based on the condition *'num. peaks > threshold'*. According to the explanation, this condition is: *'If the windows cover more than 60 percent of the given component. (Greater than 60 percent means the component worth to be rejected, this usually did not occur since EOG are just few peaks in the identified component).'* The detailed explanation is missing, covering also why 60 percent is the optimal selection, and not 50, 55, 65 or 70 percent. Figures 4-3 and 4-4 show the normalized ICA component weights for records taken from publicly available databases. Figure 4-5 shows the same for the records taken at the laboratory where the author made his research. Surprisingly, the ICA component weights for the laboratory measurements span over the negative range. The ICA component weights for the Physionet dataset and for the records made by the author are similar while the weights for the Klados dataset are different from the other two. What is the difference between the Klados dataset and the other two datasets that caused the different ICA component weights?

In thesis IV the author proposes a new method that is considered to be the basis of further research on the dynamic properties of brain networks. The scientific usability of the proposed method will be qualified based on further research. The suggested method is illustrated in Figure 5-1. The details of the branch test 'QRS OK?' should have been inserted into the text.

The thesis work is well structured and mostly fluent. The described research work establishes the four theses.

The thesis work is mostly carefully edited, however, there are misprints (a few examples: *'the ERP should only has brain activity data'* (1.5.), *'a reference signal, has to supplied'* (2.2.1), *'liner prediction method'* (7.1.), *'with sampling frequency is 360Hz'* (5.2.), ) most text editors can reveal.

Sometimes the parameter values are given with decimal places not justifiable. (E.g. 4.3.2, the comparison of three methods based on the recordings of ten subjects. The improvements of the author's method for different parameters are given as 154.61 %, 136.88 % and 388.88 %. Maximum three (rather two) decimal places should have been given.)

ERP signal amplitude is usually much less than several mV, as given in Figure 4-23. In 5.1.1.1, 'MFR' should be in place of 'MRF' (*yk > MRF).*

***In summary, I accept all theses*** but it must be stressed that thesis III and IV require further clinical validation involving numerous patients and control subjects.

***I suggest holding the thesis defense.***

Budapest, 28th October, 2020.

Ákos Jobbágy