Ontological framework for EEG analysis based upon multivariate matching pursuit

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The gold standard and common benchmark for the interpretation of electroencephalogram (EEG) is still the visual analysis of raw EEG traces by an experienced electroencephalographer. It encompasses decades of worldwide clinical and research experience, providing an invaluable knowledge base of behavioural and neurophysiological correlates. However, this knowledge is mostly phenomenological in the sense that it relates to the appearance of rhythms and structures perceived in their graphical form.

Since the first spectral analysis of EEG in 1932, algorithms provide objective quantification of EEG, offering two major advantages over the visual analysis:

1. Algorithmic implementations of the definitions of EEG structures allow us to detect weak structures in situations when low signal to noise ratio obscures their visibility even to well trained eyes.

2. Advances in the solutions to the EEG inverse problem provide information not only on the possible localisation of the neural generator of observed activity within one of the brains structures but also help to determine the likelihood of given distribution of amplitudes stemming from a dipole source within the brain.

In spite of these facts, most of the recently published studies seem to direct the efforts towards blindly replicating the experts' decisions by means of machine learning methods, rather than benefiting from the above mentioned advantages. Unfortunately, **AI learning from examples of human decisions reproduces human biases and errors**. Why this trend brings many successful applications, it does not necessarily contribute to the progress in terms of basic scientific knowledge.

In this lecture we advocate an ontological framework, based upon the following approach: multichannel EEG recordings are first decomposed by multivariate matching pursuit algorithm into waveforms (called time-frequency atoms) of well-defined time span and position, frequency, phase, and a vector of amplitudes in recorded derivations. This vector determines the spatial distribution of the given waveform's amplitudes and allows to fit a dipole model within a standard EEG inverse solution. Atoms that can be attributed to a dipole source within the brain with a goodness of fit exceeding a threshold constitute a pool of candidate waveforms reflecting brain's processes. From this pool we select waveforms with parameters conforming to the definitions of relevant structures, based upon their frequencies, time spans, and amplitudes.

To preserve the spirit of Summer School, we will start with a brief introduction of EEG and standard methods of its analysis.

For a GUI-based hands-on experience with matching pursuit and other methods of EEG analysis, Participants are welcome to try Svarog—*Signal Viewer, Analyzer and Recorder on GPL*, freely available from http://svarog.pl.