MSIAM – 2nd year internship

Coupled hidden Markov models for joint analysis of eye-movements and EEGs

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Context:

Recently, GIPSA-lab has developed computational models of information search in web-like materials, using data from both eye-tracking to get eye movements during the search and electroencephalograms (EEGs) to analyze the related neural activities. These joint datasets were obtained from experiments, in which subjects had to make some kinds of press reviews. In such tasks, reading process and decision making are closely related. Two kinds of decision are expected: A positive decision if the meaning of the text matches with the goal of information search, and a negative decision otherwise. Statistical analysis of such data aims at deciphering underlying dependency structures in these processes. Hidden Markov models (HMMs) have been used on eye movement series to infer phases in the reading process that can be interpreted as steps in the cognitive processes leading to decision – see for example Simola *et al.* (2008). In HMMs, each phase is associated with a state of the Markov chain. The states are observed indirectly through eye-movements.
However, the characteristics of eye movements within each phase tend to be poorly discriminated. As a result, high uncertainty in the phase changes arises, and it can be difficult to relate phases to known patterns in EEGs. HMMs were also used for the analysis of EEGs (Obermaier *et al.*, 2001) but coupling eye movements and EEGs in a coherent model is an unaddressed challenge.

Tasks:

The aim of the internship is to develop an integrated model coupling EEG and eye movements within one single HMM for better identification of the phases. Coupled HMMs are based on several dependent Markov chains such that at each time t, observations only depend on the states at time t (Zhong and Ghosh, 2001). Here, the coupling should incorporate some delay between the transitions in both chains, since EEG patterns associated to cognitive processes may occur with some delay with respect to eye-movement phases. Moreover, EEGs and scanpaths were recorded with different time resolutions, so that some resampling scheme must be added into the model, for the sake of synchronizing both processes. Time-scale representations of EEGs will be used as observations of HMMs, considering different scales. Inference procedures will be developed for the proposed model. Experimental data are available from eye-tracker and brain electrodes (32 EEG channels) for 15 subjects and 120 documents (60 for a positive decision, 60 for a negative one). Graphs will be inferred from the channel correlations to represent interactions between brain zones. The variability of these graphs is partly explained by individual differences in text exploration, which will have to be quantified.

Prerequisites:

Basic knowledge in discrete-state Markov chains and in mixture models is required.
Skills in Matlab, C++ or python would be appreciated.

This work is intended to be continued as a PhD thesis.

References:

B. Obermaier, C. Guger, C. Neuper and G. Pfurtscheller. Hidden Markov models for online classification of single trial EEG data. *Pattern Recognition Letters*, 22, 1299-1309 (2001).
J. Simola, J. Salojärvi and I. Kojo. Using hidden Markov model to uncover processing states from eye movements in information search tasks. *Cognitive Systems Research* 9(4), 237-251 (October 2008)
S. Zhong and J. Ghosh. A New Formulation of Coupled Hidden Markov Models, *Technical report, Dept. of Electrical and Computer Eng.*, Univ. of Texas at Austin (2001)