Large-scale cortex inspired network architectures for processing/analysis of spatiotemporal data

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The abundance of large volumes of complex spatiotemporal data is becoming reality in many research areas. An explosion of available data has also been apparent in neuroscience, particularly in brain neuroimaging and electrophysiology, as a result of technological advancement and the proliferation of research resources in the field. The increasing availability of "big data" opens up new opportunities to rigorously address a number of existing questions and propose novel challenging directions in neuroscience and its clinical applications. However, the trend has not resulted yet in the expected pace of growth in research throughput and scientific progress. One reason is that leveraging abundant data streams requires the development of novel computationally feasible methodologies for their large-scale processing. The overriding objective of such analysis is to facilitate understanding of the underlying data generating mechanisms.

Within the project scope it is intended to explore different brain-inspired strategies for handling streams of sensory information and building hierarchical representations. These inspirations should in consequence lead to the development of brain-like algorithms for exploratory search for relevant spatiotemporal data features, and a flexible inference mechanism that can benefit from both supervised and unsupervised forms of learning from data. The project draws on the experience of Prof. Anders Lansner's group at KTH Royal Institute of Technology in devising and simulating large-scale brain models on supercomputers, as well as analysing and modelling high density multielectrode array recordings in Dr Hennig's group. In particular, the project builds upon recent work undertaken in Anders Lansner's group on the use of abstract cortical models in segmentation and correlational analysis of functional magnetic resonance imaging (fMRI) (Benjaminsson et al.,) and positron emission tomography (PET) data (Schain et al.,). It is expected that the proposed project will

- review the state-of-the-art machine learning and brain-inspired methods for large-scale spatiotemporal analysis and provide a comprehensive comparative evaluation to illustrate features of the methodology being developed.
- extend the existing framework to capture spatiotemporal dependencies in neuroimaging (electroencephalography (EEG) or magnetoencephalography (MEG)) and electrophysiological (multi-unit array recordings) data at varying temporal scales, hence providing enhanced flexibility in constructing spatiotemporal representations (correlates) of brain processes, e.g. detection

of transient brain states or identification of cycles, sequences and parallel streams of neural subprocesses

- propose and incorporate new aspects of cortical information processing and representation,
- examine different strategies for building cortical model hierarchies to benefit from multi-level data representation in analysis,

In summary, a direct outcome of the proposed project is the development and critical evaluation of novel brain-like algorithms for large-scale spatiotemporal information processing with the primary focus on analysis of neuroimaging and electrophysiological recordings. The proposed methodology is aimed at revealing data structures that cast new light on mechanisms underlying the observed biological phenomena and thus support the formulation of novel hypotheses in neuroscience. Further implications embrace potential applications in clinical diagnostics where the existing approaches to analysis of EEG, MEG or PET datasets are not scalable and often serve only as discriminative, not generative, tools especially in the context of inherent non-stationary and non-linear effects. Finally, the project is intended to make a contribution to a broad field of information science by proposing a novel massively parallel and scalable (super)computational approach to processing large volumes of generic high-dimensional and non-stationary data streams.

Benjaminsson, S., Fransson, P., Lansner, A. (2010) A novel model-free data analysis technique based on clustering in a mutual information space: application to resting-state fMRI. Front. Syst. Neurosci., doi: 10.3389/fnsys.2010.00034.

Schain, M., Benjaminsson, S., Varnäs, K., Forsberg, A., Halldin, C., Lansner, A., Farde, L., Varrone, A. (2013) Arterial input function derived from pairwise correlations between PET-image voxels. J Cereb Blood Flow Metab. 33: 1058-1065.