Information Theoretic Analysis of Biomedical Time Series and Images

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The predominant goal of our activities within the project ModKog were concerned with developing new and efficient statistical and information-theory-based tools to analyze biomedical data sets like fMRI, MEG etc. The basic concept of our approaches was independent component analysis, a mathematical concept to solve the blind signal separation problem. The underlying hypotheses is that recorded signals, images or data sets can be decomposed in statistically independent or uncorrelated components, which eventually may turn out to be more informative and elusive than the original data. Most of the algorithms we developed focus on spatial and /or temporal correlations in the data as additional information, hence second order techniques sufficed to solve the problems at hand.

As biomedical signal are notoriously very noisy, we developed denoising algorithms based on local projective denoising techniques like localICA combined with an MDL parameter estimator or dAMUSE which solves the BSS problem in a feature space of lagged or shifted coordinates.

Concerning the identification of interesting components we developed an automatized search tool called incomplete ICA. It groups reproducibly similar or identical independent components and replaces them by a corresponding prototype component. Thereby the dimensionality of the problem is reduced drastically without giving away any information contained in the components. The tool showed a superior performance on fMRI data corresponding to a Wisconsin card sorting test.

Usually 2dim data sets are transformed to 1dim data by concatenating the rows of the data matrix. Thereby many of the potentially informative correlations are broken. We thus extended the well-known algorithm SOBI to multi-dimensional data sets, like fMRI data matrices, using mulit-dimensional auto-covariances which become jointly diagonalized. Application to fMRI data sets revealed a much better performance than classical ICa algorithms.

Analyzing temporal correlations in fMRI data sets is difficult because of a lack of sufficient data points. We developed windowed ICA as a possible solution to this problem, where we take into account the non-stationarity of fMRI data sets. The ICA analysis is performed on suitably chosen time-windows of the activation time series of each voxel. Moving the window along the time series and performing an ICA analysis each time we can follow slowly varying changes of the extracted independent components. Performance of the algorithm has been tested on fMRI data sets derived from auditory stimuli. The time dependence of the extracted components can be visualized very well this way.

Merging everything together we finally developed a tool called spatio-temporal ICA where we extract components which are spatially and temporally independent. This is especially useful in case of fMRI data sets which represent time series of MRI images. The algorithm turned out to be very robust against outliers and showed a superior performance compared to well-known classical algorithms like fastICA, infomax etc.