Fundamental Theory of Brain Decoding and its Applications to Non-verbal Information Retrieval

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1. Objective

This project is aimed at: development of brain decoding technique using functional magnetic resonance imaging (fMRI) and electro encephalography (EEG). We have studied nonverbal multimedia information retrieval, particularly content-based image retrieval using computational intelligence algorithms (See [1-3]). For more two years the brain computer interface (BCI) based has been under way at KUT. The core idea comes from brain decoding a novel technique in neuroscience (See [4, 5]). To improve brain decoding performance is an urgent requirement for the realization of BCI-based nonverbal information retrieval. Brain activity measurement techniques and algorithms for machine learning for brain decoding will be developed in this project.

2. Project Outline

To that end, the project will consist of the following phases:

(a) Establishment of preprocessing signals and extracting features of fMRI/EEG brain activity data.
(b) Creation, implementation and refinement of machine learning algorithms using supervised and unsupervised algorithms for brain decoding.
(c) Realization of a brain decoding methodology for nonverbal multimedia information retrieval using the above techniques.

3. Expected Performance

In this project, the successful candidate would be expected to:

(a) Understand the basic principles of neural activity in the human brain and brain measurement devices such as fMRI and EEG, including the ability to determine appropriate parameters of fMRI and EEG.
(b) Read related international journal papers independently and discuss with senior researchers.
(c) Conduct brain activity measurement experiments.
(d) Understand the theory of machine learning algorithms.
(e) Publish outcomes of research results in international journal papers, and present them at international conferences.

4. Required Skills and Knowledge

The successful candidate for this project will have the following knowledge and skills:

(a) Mathematical theories related to machine learning and computational intelligence, e.g., kernel trick for support vector machine (SVM), regression (SVR), and clustering (SVC). Linear algebra for singular value decomposition (SVD) and probability, statistics for Bayesian inference and particle filter (sequential Monte Carlo filter or extended Karman filter) are also required.
(b) Programming skill to implement above algorithm using C/C++/Matlab. Programming skills using MPI (Message Passing Interface) on Linux clusters may highly improve result of research.
(c) Ability to communicate and discuss in English.

References

[1] SUN, Liang; YOSHIDA, Shinichi; CHENG, Xiaochun; LIANG, Yanchun; "A Cooperative Particle Swarm Optimizer with Statistical Variable Interdependence Learning," Information Sciences, Vol. 186, No. 1, pp.20-39, 2012

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[3] SUN, Liang; GE, Hongwei; YOSHIDA, Shinichi; LIANG, Yanchun; TAN, Guozhen, "Support vector description of clusters for content-based image annotation," Pattern Recognition, available online 18 October 2013, to be printed in 2013

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[5] KAMITANI, et al., "Reconstructing Visual Experiences from Brain Activity Evoked by Natural Movies," Nature Neuroscience, 8(5), pp.679-685, 2005

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