Guest Editorial Multimodal Modeling and Analysis Informed by Brain Imaging—Part II

Abstract—**Human brains are the ultimate recipients and assessors of multimedia contents and semantics. Recent developments of neuroimaging techniques have enabled us to probe human brain activities during free viewing of multimedia contents. This special issue mainly focuses on the synergistic combinations of cognitive neuroscience, brain imaging, and multimedia analysis. It aims to capture the latest advances in the research community working on brain imaging informed multimedia analysis, as well as computational model of the brain processes driven by multimedia contents. This issue contains the second set of papers from the double Special Issue.**

Index Terms—**Affective computing, brain computer interface, brain imaging, brain-informed multimedia analysis.**

I. The Scope of this Special Issue

A challenging problem facing multimedia content analysis is the semantic gap between the high-level perception and cognition in the human brain and the low-level features embedded in digital contents. The human brain is the ultimate recipient and assessor of multimedia contents and semantics. Deep understanding of the brain's responses to multimedia will fundamentally advance the computational strategies for multimodal representation, classification and retrieval.

We envision a future with a seamless integration between cognitive neuroscience, a discipline related to the principle and mechanisms of the brain, and computer science, a discipline designing automated digital algorithms. Examples of such integration include neural network algorithms, which could reduce the semantic gap by mimicking the neural processes in the brain. Conversely, applications of automated computer algorithms have advanced our understanding of the brain. In the recent years, we have witnessed the emergence of novel brain-guided or brain-informed techniques in multimedia analysis and modeling, including computational visual attention models, sparse representation techniques, and deep learning techniques. These techniques have been applied to object recognition, image categorization, image/video compression, image/video retrieval, and video summarization.

The remarkable development of neuroimaging techniques such as functional magnetic resonance imaging (fMRI), electroencephalography (EEG), and magnetoencephalography (MEG), has enabled us to probe the human brain in natural settings such as free viewing of multimedia contents. This development is leading a new trend that applies neuroscience and neuroimaging to assisting multimodal analysis and modeling. This new methodology has considerably narrowed the gaps between the low-level multimedia features and the high-level semantics. In parallel, neuroimaging combined with naturalistic stimuli such as films and music also provide neuroscientists an intriguing opportunity to examine the brain circuitry underlying natural experience.

II. Contribution To The Special Issue

This Special Issue incorporates 17 papers. Here we summarize the content of the second set of eight papers (see the September 2015 issue for the first set of nine papers).

How the brain self-wires, develops and computes, prenatally and postnatally are still far from being well understood. By assuming that the brain development is multimodal via interactions with the external environment, Song *et al.* [1] in their paper entitled "*Types, Locations and Scales from Cluttered Natural Video and Actions*," propose to model the autonomous development of brain-inspired circuits by synchronizing two modalities of video stream and action stream in time. Based on it, a framework capable of learning object location, type, and scale in cluttered backgrounds is developed for a general purpose developmental program. Experimental results on large-scale natural video data can demonstrate the superiority of the proposed framework.

In the paper entitled "*Randomized Structural Sparsity based Support Identification with Applications to Locating Activated or Discriminative Brain Areas: A Multi-center Reproducibility Study*," Wang *et al.* [2] propose a randomized structural sparsity approach to identify support regions for the purpose of locating activated or discriminative brain areas. Experiments on multi-center data show consistent and stable result, which are better than other compared methods such as two sample t-test. This work could potentially contribute to biomarker discovery using functional or structural MRI.

The article by Zarjam *et al.* [3] is titled "*Beyond Subjective Self-Rating: EEG Signal Classification of Cognitive Workload*." The authors measure and classify the level of working memory workload of human subjects using EEG signals. They argue that compared with subjective self-assessment, the use of EEG signals has the advantages of on-line and continuous measurement during the cognitive task. They find that the entropy, energy, and standard deviation of the wavelet coefficients consistently correlated with the induced load. To indicate the relatively effectiveness of the EEG-based method, they also compare their results with alternative measures including performance, subjective ratings, and response time of the subjects. They conclude that EEG is the preferred measure of working memory load in the application context they studied.

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In neuroimaging field, the fusion of multiple modalities such as EEG and fMRI is a hot research topic in the recent years as it is highly desired by many clinical applications [4]. Dong *et al.* [5] in their paper entitled "*Local Multimodal Serial Analysis for Fusing EEG-fMRI: A New Method to Study Familial Cortical Myoclonic Tremor and Epilepsy*," present an unsupervised approach called local multimodal serial analysis for integrating EEG modality and fMRI modality. This approach is able to emphasize the common substrate of modalities, decrease uncertainty in fusion of EEG-fMRI, and compensate for deficiencies.

An urgent need in psychiatry research and practice is to establish neurobiology-based diagnostic criteria. Neuroimaging offers a noninvasive tool to examine the function and structure of the brain, and hence holds great potential for improving diagnosis in psychiatry. While machine learning methods have been used to select diagnostic features from neuroimaging data, proper clinical or neurobiological interpretations of the selected features, however, are often challenging. To address this problem, Jie *et al.* [6] propose a novel classification method with a forward-backward search strategy, termed as SVM-FoBa. In the article "*Discriminating Bipolar Disorder From Major Depression based on SVM-FoBa: Efficient Feature Selection with Multimodal Brain Imaging Data*," they apply SVM-FoBa to multimodal neuroimaging data to differentiate unipolar depressive disorder and bipolar disorder, a common diagnostic problem in psychiatry practice. Not only SVM-FoBa achieves high accuracy in the classification, but also identifies anatomical features consistent with prior neuroscience knowledge. These promising results support the potential application of SVM-FoBa in identifying neuroimaging-based biomarkers for mental disorders.

Brain computer interface (BCI) is the core technology driving much of the innovation in the health sector today. Its core mission is to interpret commands in the brain based on invasive or non-invasive neural recordings, and use these commands to control computers and machines. Typically, non-invasive BCI technologies rely on either stimulus-evoked signals, such as Steady-state visual evoked potential (SSVEP) and P300 potential, or spontaneous signals, such as EEG signals during motor imagery without external stimuli. Duan *et al.* [7] propose an innovative hybrid BCI system that combines SSVEP and motor imagery. As presented in the article "*Design of a Multimodal EEG-based Hybrid BCI System with Visual Servo Module*," this hybrid BCI design employs both SSVEP and motor imagery for the control of robotic movements. Simulation as well as tests with humanoid robot demonstrate the feasibility and validity of this hybrid BCI design.

In the paper entitled "*EEG-based Perceived Tactile Location Prediction*," Wang *et al.* [8] propose to employ single-trial EEG measurements to explore the perception of tactile stimuli located on participants' right forearm. Then an EEG-based signal analysis approach is developed to predict the location of the tactile stimuli. Experimental results demonstrate good accuracy. This work could potentially contribute to the development of real-time reactive control machine for the clinic.

In their paper entitled "*An Adaptive Motion-Onset VEP-based Brain-Computer Interface*," Zhang *et al.* [9] propose to employ the amplitudes of three components of mVEP to build a dynamic stopping criteria according to the practical information transfer rate (PITR) from the training data. The experimental results show that this dynamic stopping strategy could substantially improve the communication efficiency of mVEP-based BCI, which could contribute to real life BCI applications.

In summary, the described seventeen papers in this double Special Issue report their new progress and results in exploring neuroimaging techniques to assist multimodal analysis, examine the functional and structure of the brain, and develop brain computer interface. Based on the achievements of these works, we believe that the integration of neuroimaging and multimedia can significantly advance our understanding on how the human brain perceive, process and assess multimodal contents, as well as developing effective algorithms for multimedia analysis.

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