

# Guest Editorial for Special Section on Multimodal Biomedical Imaging: Algorithms and Applications

**J**OINTLY assessing data from multiple modalities is inherent to many problems in science and engineering, but it is especially relevant to the analysis of biomedical imaging data. Technologies for imaging are individually expensive; thus, ways to synergistically derive information from complementary modalities are clearly attractive. Moreover, for instance, since each brain imaging modality is an indirect reflection of underlying neural activity at a different spatiotemporal scale, the emergence of multimodal neuroimaging analyses provides an unprecedented opportunity for understanding normal brain function and the pathophysiology of many brain diseases.

Due to the sheer volume and increasing complexity of multimodal biomedical imaging data, there is critical need for new, advanced multimedia signal processing, modeling and computational methods. Such methods need to be fast, accurate and cost-effective means to probe underlying biological processes for novel imaging modalities to be adopted in real-world applications. Traditionally, biomedical imaging data has been analyzed from the approach of signal or image processing, but these submissions likely were published in journals outside the IEEE TRANSACTIONS ON MULTIMEDIA (TMM). With this special section, we would like to encourage future biomedical imaging submissions to TMM, and alert the multimedia community of the potential of multimodal biomedical imaging—an area of growing significance. The goal of this special section has been to bring together the imaging and media analysis communities to provide a diverse, but complementary, set of contributions to demonstrate the importance of multimedia signal processing and machine learning approaches in the multimodal biomedical imaging area.

Through an open call for papers, we received 24 submissions, and after two rounds of professional reviews, nine papers were accepted for final publication. The final papers represent the state-of-art of this important and rapidly developing interdisciplinary area. This issue of TMM will provide a broad view of the recent advances in the wide field of multimodal biomedical imaging with respect to concepts, data acquisition, data analysis and fusion, and medical validation and direct clinical application.

The first three papers are invited review papers. Multimodality optical imaging is one fast-emerging exciting area, especially when combined with other modalities, such as ultrasound. Such photoacoustic tomography (PAT) can overcome the fundamental penetration depth problem of light yet still achieve high-resolution optical imaging in deep tissues. The paper by Jeon and Kim, “*Multimodal Photoacoustic*

*Tomography*”, reviews the multimodal imaging capability of PAT, integrated with existing imaging tools, and discusses the potential preclinical and clinical impacts of the combined systems.

A current shift in surgical procedures has been made from traditional open surgery—requiring a large incision to expose the site to be operated on to the surgeons’ visual field—to the use of minimally invasive procedures. The field of image-guided interventions is still evolving, but registration is a key for any computer-aided image guidance. The paper by Liao *et al.*, “*A Review of Recent Advances in Registration Techniques Applied to Minimally Invasive Therapy*”, provides a thorough survey on the recent advances in registration techniques applied to minimally invasive therapy, including a wide variety of therapies in surgery, endoscopy, interventional cardiology, interventional radiology, and hybrid procedures. When EEG is one of the modalities used in fusion, it is desirable to relate a nonlinear function of the raw EEG signal, such as EEG band power, to another modality such as the hemodynamic response, measured by NIRS or fMRI. In the paper by Dahne *et al.*, “*Integration of Multivariate Data Streams With Bandpower Signals*”, the authors review such techniques and present an approach to tackle this problem whose performance is studied for simulated and real-world multimodal data.

The next five papers address multimodal data fusion with a focus on specific medical applications. The paper by Bhatnagar *et al.*, “*Directive Contrast Based Multimodal Medical Image Fusion in NSCT domain*”, addresses multimodal image fusion based on the non-subsampled contourlet transform, a powerful multiscale directional transform. Several examples from clinical neuroimaging are shown, illustrating the interest to merge information from CT, different MRI contrasts, and PET/SPECT images.

Molecular imaging has provided excellent potential to visualize and characterize biological processes within intact living animals. Fluorescence imaging and [<sup>18</sup>F]FDG – PET can provide complementary and cross-validation information at the molecular scale. The paper by Liu *et al.*, “*Monitoring of Tumor Response to Au Nanorod-Indocyanine Green Conjugates Mediated Therapy With Fluorescence Imaging and Positron Emission Tomography*”, employs both fluorescence imaging and [<sup>18</sup>F]FDG – PET to monitor tumor response and suggests that such a combination could provide a noninvasive tool to assess the tumor response to antitumor therapy on a molecular scale. In the paper by Zhang *et al.*, “*Fluorescence Tomography Reconstruction With Simultaneous Positron Emission Tomography Priors*”, the target prior information from simultaneous PET images is integrated into the fluorescence molecular

tomography reconstruction procedure, and the proposed procedure is tested by simulations and phantom experiments.

In the paper by Lagana *et al.*, “*Transcranial Ultrasound and Magnetic Resonance Image Fusion With Virtual Navigator*”, it suggests that investigation of deep cerebral veins and dural sinuses can highly benefit from the fusion of transcranial ultrasound with MRI. In this work, facial anatomical landmarks are incorporated in the multimodal registration framework to establish better navigator technology.

Inter-subject variability is a common concern in medical applications, and therefore group analysis is a challenging topic. The paper by Chen *et al.*, “*A Joint Multimodal Group Analysis Framework for Modeling Corticomuscular Activity*”, focuses on corticomuscular coupling analysis by looking into relationships between EEG and EMG for better understanding of human motor control systems, which can be altered in diseases of motor control, such as Parkinson’s disease. In particular, the coupling of EEG and EMG signals acquired at different electrodes is a particularly useful feature. A new framework for joint multimodal analysis of these measures is proposed with special attention to model intra- and inter-subject variability.

The last paper explores an interesting real-world application in the area of multimodal human-machine interfaces and interaction. The paper by Cong *et al.*, “*Linking Brain Responses to Naturalistic Music Through Analysis of Ongoing EEG and Stimulus Features*”, represents an early attempt to analyze ongoing EEG in real-world naturalistic and continuous music listening experiences.

The papers selected in this special section, we believe, bring together a snapshot of the latest research in the exciting and fruitful field of multimodal biomedical imaging. We hope that this collection will help identify the important issues in biomedical image analysis and the key challenges to the multimedia and signal processing communities and will help bring together researchers from different disciplines to accelerate growth of this promising field. The guest editorial team would like to acknowledge all authors for their outstanding contributions and the reviewers for their thoughtful comments. We are also grateful to Dr. Mihaela van der Schaar, the Editor-in-Chief of TMM, for her gracious support of the special section and to Ms. Rebecca

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We hope that you will enjoy reading this special section as we enjoyed putting it together.

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