The skyrocketing medical expenditures and aging of the world's population demand transformative technological innovations to provide more effective and affordable healthcare services to anyone at any time and in any place. The past decade has witnessed the rapid growth of advanced information technologies that promote the conventional medical research into a new era. For example, recent advances in 3D printing have enabled bio-compatible materials, cells and supporting components into complex 3D functional living tissues. Physicians are using Google Glass to stream their operations online, float medical images and monitor the patient’s vital signs in their field of view, and hold video consultations with colleagues as they operate. Deep machine learning methods, which were conventionally used in the areas of speech, signal, image, video and text mining, have recently made notable advances in the tasks of classification and representation learning of brain imaging and neuroscience discovery. 3D fingerprinting has emerged as a promising biometric authentication approach in the increasing vulnerable cyber world, leveraging the acoustic ultrasonic in a way that high-frequency acoustic waves penetrate the inner dermal layer of skin to extract the unique print, down to the ridges on the skin and even the sweat pores. Researchers found that children who were found to have autism at older age looked less at people's eyes when they were babies than children who did not develop autism, suggesting that tracking a baby's eye movement may lead to earlier autism detection. The increasing popularity of smartphones and wearable devices hold the potential of transforming the conventional, hospital-centered healthcare system into individual-centric, personalized, preventive healthcare approach, where devices at home are capable of collecting physical and physiological information, analyze the data, diagnose the problem, and send the results to a physician who could treat them remotely. Last, facilitated by the intersection of state-of-the-art neuroscience, brain-computer interfaces, and robotics, veterans and civilians with disability are given the hope of moving artificial robotic limbs using only their thoughts and even getting sensory feedback from their robotic hands. All aforementioned examples have fully demonstrated the increasingly significant role and impact of advanced technologies, especially computers and electrical engineering techniques, in shaping the effectiveness and efficiency of existing healthcare systems, as well as promoting the next generation of research innovations in biology, chemistry, neuroscience, medicine, and psychology. On the other side, it has also seen the evolution of new interdisciplinary research areas – bioinformatics, synthetic biology, nanobiology, computational biology, tissue engineering, biomaterials, and systems biology are examples. These new fields share a comparable, underlying research model, a true disciplinary integration.

In recent years, aligned with those cross-disciplinary technological innovations, people pay particular attention and emphasis on a timeless concept – “Convergence” – to describe a Third Revolution: one that merges the life and physical sciences with engineering to produce the scientific advances of the future. According to an white paper by 12 leading MIT researchers, published in 2011 [1], “convergence is a new paradigm that can yield critical advances in a broad array of sectors, from health care to energy, food, climate, and water.” As recommended in this report, “convergence is not just about collaboration, but rather about jointly applying the fundamentally different approaches that each discipline brings to a problem.” For example, a Boston-area research company, BioMEMS Resource Center, has created a device that detects even very the smallest amounts of cancer cells in a patient’s blood samples. The device took the collaboration of physicists to calculate the optimal flow of blood through the chip, engineers to construct the tiny chip, biologists to attach the appropriate antibodies to the chip, and clinicians to test the chip under real-world conditions.

In parallel with the advances in emerging science and technology, there are still immense demands on techniques that can solve the conventional research problems in a more effective and efficient manner. For example, signal processing is still an extensively explored, longstanding topic which holds a critical role in the analysis of various physical, physiological, and biological signs and symptoms measured from the human body invasively or noninvasively through a variety of sensors and
Instruments developed through decades. As another example, fast and more accurate image processing approaches have constantly been investigated and pursued by researchers to accommodate the increasing needs for finer-grained, multivariable structural brain imaging and mapping. Similarly, joint EEG-fMRI or EEG-NIRS allows exploitation of both high time resolution of EEGs and good spatial resolution of fMRI or NIRS in better detecting and locating event and movement related brain sources. Other areas of interest have included developing tools and algorithms for processing of heart and lung sounds, cardiovascular MRI, human joint sounds, impedance imaging, and microwave imaging. In addition, segmentation of eye retina images, vascular systems, and the assessment of a series of physiological, pathological, or biological measurements have been widely researched.

Following the previous special issues published in this Journal [2–4], in this special issue we have covered some of the developments in the domain of biomedical signal, image processing and biometrics. Of course it is not possible to cover all aspects mentioned above in this special issue. The summary and the importance of the topics covered in this issue have been given here.

The first three papers focus on biomedical signal processing. Sharma presents a multiscale compressed sensing based processing approach for electrocardiogram (ECG) signals, with the goal of largely preserving the pathological information and clinical information in compressed measurements that can be further used for recovering the original sparse ECG signals. Upadhay et al. propose a systematic vigilance level detection methodological framework, consisting of three steps: EEG channels selection, feature extraction and classification. Specifically, the maximum energy to Shannon entropy ratio was applied to select appropriate EEG channels; three nonlinear features such as Higuchi fractal dimension, Petrovsk fractal dimension and Detrended Fluctuation Analysis were calculated to prepare three feature vectors; and then three machine learning techniques were used for vigilance level detection, including support vector machine, least square support vector machine, and artificial neural network. Mateo et al. address the issue of removing powerline interference (primarily 50 Hz or 60 Hz), a major source of noise in electrophysiological recordings (such as ECG and EEG), by adopting a radial basis function (RBF)-Wiener hybrid filter leveraging the merits of both filters.

The next three papers primarily discuss the recent research in biometrics, given its increasing applicability and significance in a wide range of security applications. Usha and Ezhilarasan give a comprehensive review about the use of finger knuckle surface as a biometric, which is considered as one of the emerging biometric traits given its stable and unique inherent patterns. The potential challenges that could arise during the implementation of large-scale, real-time, finger knuckle print based biometric systems were also explored. Alqudah and Al-Zoubi focus on another widely investigated and important biometric method, face recognition, by adopting a classification approach during the training phase combined with self-organizing-maps, and report a very high recognition rate (about 97%). Recently, three-factor remote authentication (i.e., password, memory device, and biometrics) has gained increasing attention to ensure secure network communications. Wu et al. propose a new three-factor remote authentication scheme using elliptic curve cryptography, which demonstrates the advantages of better usability and security.

The third group contains four papers, primarily investigating the applications of state-of-the-art biomedical imaging technologies. It has been well recognized that biomedical imaging technologies have been playing more important roles in clinical diagnosis and treatment. However, there still are many challenges in analyzing and interpreting the biomedical images because of their noisy and ambiguous nature. Automated recognition of brain tumors in magnetic resonance images (MRI) is a difficult procedure due to the variability and complexity of the location, size, shape, and texture of these lesions. Nabizadeh and Kubat propose a fully automatic system using single-spectral anatomical MRI scans to detect slides that include tumor and, to delineate the tumor area. The proposed approach has higher accuracy and lower computational complexity, compared to the conventional schemes based on multi-spectral MRI scans. Also, a comparative study was conducted for evaluating the efficacy of statistical features over Gabor wavelet features using several classifiers. Gandhi proposes a method to detect lesion exudates automatically with the aid of a non-dilated retinal fundus image to help ophthalmologists diagnose the diabetic retinopathy, which occurs in individuals with several years of diabetes mellitus and cause a characteristic group of lesions in the retina. The exudates from the low contrast images are detected and localized using a neighbourhood based segmentation technique. A support vector machine (SVM) and probabilistic neural network (PNN) classifiers were used to assess the severity of the disease. Li and Xie present a new medical image enhancement method that adjusts the fractional order according to the dynamic gradient feature of the entire image. Specifically, the proposed Adaptive Fractional Differential Algorithm (AFDA) uses the improved Otsu algorithm to segment the edges, textures and smooth areas of images, which was shown to be able to make edges clearer and textures richer. Somasekar and Reddy propose an automatic segmentation method, including pre-processing and post-processing stages, for the erythrocytes infected with malaria parasites using microscopic imaging for the diagnosis, where pre-processing corrects luminance differences of a gray scale image obtained from a color microscopic image and fuzzy C-means clustering was applied to extract infected erythrocytes in the post-processing. The results show that the proposed segmentation method can achieve very high sensitivity (SE), specificity (SP), prediction value positive (PVP) and prediction value negative (PVN).

The last paper represents the recent advances and research efforts in the area of implantable and wearable microelectronics for biomedicine. A backside illuminated image sensor was designed by Ghormishi and Karami as epiretinal prosthesis implant, using the 90 nm CMOS technology. The image sensor consists of a p-sub/n-well structure as the photosensitive area with the pixel pitch of 20 μm. Ninety percent quantum efficiency at 600 nm wavelength and the dark current of 74.6 nA/cm² at room temperature are achieved for the optimized pixel. The application of deep backside Deep Trench Isolation (DTI), with high depth n-well doping profiles, results in a significant reduction of crosstalk (5.6% total crosstalk).
It is anticipated that, the above manuscripts collected in this special issue will stimulate and generate new seeds for future thoughts.

References

[3] Special Issue on Recent advances in signal processing, biomedical engineering and informatics, vol. 39(5); July 2013.

Guest Editors

Mohammad Reza Daliri

Biomedical Engineering Department, Faculty of Electrical Engineering, Iran University of Science and Technology (IUST), Tehran, Iran

School of Cognitive Sciences (SCS), Institute for Research in Fundamental Sciences (IPM), Tehran, Iran

E-mail address: daliri@iust.ac.ir

Zhanpeng Jin

Departments of Electrical and Computer Engineering, and Biomedical Engineering, Binghamton University, State University of New York, USA

E-mail address: zjin@binghamton.edu

Mohammad Reza Daliri received his PhD from the International School for Advanced Studies (ISAS/SISSA), Trieste, Italy in 2007. After his PhD, he received a funding (for 6 months) from International Center for Theoretical Physics (ICTP), Trieste, Italy as an opportunity to undertake training and research in an Italian laboratory (TRIL programme). He then moved to Cognitive Neuroscience Laboratory, German Primate Center (DPZ), Goettingen, Germany as a postdoctoral researcher. Since then he has been a member of academic staff in Iran. Currently he is an Associate Professor in the Department of Biomedical Engineering, Faculty of Electrical Engineering, Iran University of Science and Technology (IUST), Tehran, Iran. He has served as a member of editorial boards for several international journals and a member of technical program committees of different international conferences. His main research interests include brain signal processing, computational and cognitive neuroscience, pattern recognition, and computer vision (mainly for biomedical applications).

Zhanpeng Jin is currently an Assistant Professor in Departments of Electrical and Computer Engineering, and Biomedical Engineering, and the Director of Cyber-Med Laboratory at the Binghamton University, State University of New York (SUNY), USA. Prior to joining SUNY-Binghamton, he was a Postdoctoral Research Associate at the University of Illinois at Urbana-Champaign (UIUC) and received his Ph.D. degree in Electrical Engineering from the University of Pittsburgh. His research interests include mobile and wearable computing in health, neural engineering, neuromorphic computing, low-power sensing, and body sensor networks. He serves on the editorial boards for five international journals and on the Technical Program Committees for more than a dozen of conferences. He is a member of Sigma Xi, IEEE, IEEE Computer Society, and IEEE Engineering in Medicine and Biology Society.