Emerging Technologies for Patient-Specific Healthcare

I. Introduction

PATIENT-SPECIFIC healthcare is a research field that has recently garnered much more attention due to the benefits of better services provided to patients and a reduction of healthcare costs. A series of emerging technologies [1] aim to emphasize the provision of personalized healthcare services to patients [2]–[5]. These include the following.

1) Pattern recognition methods for signal pattern classification toward the prediction and diagnosis of diseases.
2) Body sensor networks.
3) Algorithms for the analysis of patient-specific physiological signals.
4) Ontologies and context-based electronic health records (EHRs).
5) Methodologies for the integration of clinical, imaging, and genetic data.
6) Diagnostic and therapeutic systems based on physiological signals.
7) Modeling of physiological systems.
8) Monitoring and treatment support tools for chronic diseases.
9) Patient-specific multiscale modeling.
10) Data mining algorithms targeted to biomedical domains.
11) Integrated e-health solutions.

Papers in this special issue address the aforementioned topics, which cover a wide range of emerging technologies used for patient-specific healthcare in different applications and domains.

II. Special Issue

The special issue, *Emerging Technologies for Patient Specific Healthcare*, is in reference to the 10th IEEE International Conference on Information Technology and Applications in Biomedicine (http://medlab.cc.uoi.gr/itab2010/), which took place in Corfu, Greece, November 2–5, 2010. The special issue consists of 16 papers, which are all analyzed and discussed in the following.

In [6], the authors propose a nonlinear cascade model to predict the subthalamic nucleus spike activity from the local field potentials recorded in the motor area of the nucleus of Parkinson's disease patients undergoing deep brain stimulation. The results prove the ability of the model to provide quite accurate predictions for multiple-neuron recordings and establish its validity as a simple, yet biologically plausible model of the intranuclear spike activity recorded from Parkinson's disease patients.

A new Neural Sensing Healthcare System for 3D Vision Technology, NeuroGlasses, is presented in [7]. NeuroGlasses is a nonintrusive, wearable physiological signal monitoring system to facilitate health analysis and diagnosis of 3-D video watchers. The NeuroGlasses system acquires health-related signals by physiological sensors and provides feedback of health-related features. The system employs signal-specific reconstruction and features extraction to compensate the distortion of signals caused by the variation of sensor placement. Through an on-campus pilot study, the experimental results show that NeuroGlasses system can effectively provide physiological information.

In [8], the authors explore how the rhythmogram can be used to provide rigorous control of natural continuous stimuli like music and speech. The analysis correlates important features in the time course of stimuli with corresponding features in brain activations elicited by the same stimuli. Correlating the identified regularities of the stimulus time course with the features extracted from the activations of each voxel of a tomographic analysis of brain activity provides a powerful view of how different brain regions are influenced by the stimulus at different times and over different (user-selected) timescales. The application of the analysis to tomographic solutions extracted from Magnetoencephalographic data recorded while subjects listen to music reveal a surprising and aesthetically pleasing aspect of brain function; an area believed to be specialized for visual processing is recruited to analyze the music after the acoustic signal is transformed to a feature map. The methodology is ideal for exploring the processing of complex stimuli (i.e., linguistic structure and meaning and how it fail), for example, in developmental dyslexia.

An individualized transfer function (ITF) for subject-specific estimation of central aortic blood pressure is presented in [9]. Initial proof of principle for the ITF is demonstrated experimentally through an *in vivo* protocol. In swine subjects taken through wide-ranging physiologic conditions, the ITF was on average able to provide central aortic blood pressure waveforms more accurately than a non-ITF. Its usefulness was most evident when the subjects' pulse transit time deviated from normative values. In these circumstances, the ITF yielded statistically significant reductions over a non-ITF.

Numerical characterization and modeling of subject-specific ultra wideband body-centric radio channels and systems for healthcare applications is presented in [10]. The employed technique is well suited to model the radio propagation around complex, inhomogeneous objects such as the human body. The

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impact of different digital phantoms in on-body radio channel and system performance was studied and simulations were performed at the frequency of 3–10 GHz considering a typical hospital environment, and were validated by on-site measurements with reasonable agreement. The analysis demonstrated that the characteristics of the on-body radio channel and system performance are subject specific and are associated with human genders, height, and body mass index. Maximum variation of almost 18.51% is observed in path loss exponent due to change of subject, which gives variations of above 50% in the system bit error rate performance. The authors conclude that careful consideration of subject-specific parameters is necessary for achieving energy efficient and reliable radio links and system performance for body-centric wireless network.

Authors in [11] describe their work toward creating a context-based EHR, which employs biomedical ontologies and disease models as sources of domain knowledge to identify relevant parts of the record to display. Their hypothesis is that knowledge from these sources can be used to standardize, annotate, and contextualize information from the patient record, improving access to relevant parts of the record and informing medical decision making. To achieve this, authors describe a framework that aggregates and extracts findings and attributes from free-text clinical reports, maps findings to concepts in available knowledge sources, and generates a tailored presentation of the record based on the information needs of the user. The framework has been implemented in a system called AdaptEHR, demonstrating its capabilities to present and synthesize information from neurooncology patients.

An ontology for modeling multidisciplinary treatment schemes utilizing semantics is analyzed in [12]. The SEMantic PATHways (SEMPATH) ontology comprises three main parts: 1) the clinical pathway, b) the business and finance, and c) the quality assurance. The implementation achieves the conceptualization of the multidisciplinary domain of healthcare provision in order to be further utilized for the implementation of a semantic Web rules (SWRL rules) repository. Finally, the SEMPATH ontology is utilized for the definition of a set of SWRL rules for the human papilloma virus disease and its treatment scheme.

Authors in [13] present the latest progress made concerning a hybrid diagnostic and therapeutic system able to provide focused microwave radiometric temperature and/or conductivity variation measurements and hyperthermia treatment. Previous experimental studies of the same group have demonstrated the system performance and focusing properties in phantom as well as human experiments. The system is able to detect temperature and conductivity variations with frequency-dependent detection depth and spatial sensitivity. Numerous studies have also demonstrated the improvement of the system focusing properties attributed to the use of dielectric and left-handed matching layers. In this study, similar experimental procedures are performed but this time using an anatomical head model as phantom aiming to achieve a more accurate modeling of the system's future real function.

The work in [14] proposes a prototype of a medical expert system that could significantly aid medical experts to detect hemodynamic abnormalities (increased artery wall shear stress). Based on the acquired simulated data, authors apply several methodologies for: 1) predicting magnitudes and locations of maximum wall shear stress in the artery; 2) estimating reliability of computed predictions; and 3) providing user-friendly explanations of the model's decision. The obtained results indicate that the evaluated methodologies can provide a useful tool for the given problem domain.

In [15], the authors deal with high-grade glioma diffusive modeling. Diffusive models of glioma growth use variations of the diffusion reaction equation in order to simulate the invasive patterns of glioma cells by approximating the spatiotemporal change of glioma cell concentration. The most advanced diffusive models take into consideration the heterogeneous velocity of glioma in gray and white matter by using two different discrete diffusion coefficients in these areas. Moreover, by using diffusion tensor imaging (DTI), they simulate the anisotropic migration of glioma cells, which is facilitated along white fibers, assuming diffusion tensors with different diffusion coefficients along each candidate direction of growth. This paper extends this concept by fully exploiting the proportions of white and gray matter extracted by normal brain atlases, rather than discretizing diffusion coefficients. Moreover, the proportions of white and gray matter, as well as the diffusion tensors, are extracted by the respective atlases; thus, no DTI processing is needed. The model is applied on real data and the results indicate that rates for prognosis can be improved.

In [16], the main objective is to present a distributed processing architecture that explicitly integrates capabilities for its continuous adaptation to the medium, the context, and the user. This architecture is applied to a falling detection system through: 1) an optimization module that finds the optimal operation parameters for the detection algorithms of the system devices; and 2) a distributed processing architecture that provides capabilities for remote firmware update of the smart sensors. The smart sensor also provides an estimation of activities of daily living (ADL), which results in very useful monitoring of the elderly and patients with chronic diseases. The experiments have demonstrated the feasibility of the system and specifically the accuracy of the proposed algorithms and procedures (100% success for impact detection, 100% sensitivity and 95.68% specificity rates for fall detection, and 100% success for ADL level classification).

In [17], the results of the ARTreat project, which deal with multiscale modeling of atherosclerosis, are presented. A continuum-based approach for plaque formation and development in three dimensions is presented. The blood flow is simulated by the 3-D Navier–Stokes equations, together with the continuity equation, while low-density lipoprotein (LDL)transport in lumen of the vessel is coupled with Kedem–Katchalsky equations. The inflammatory process is solved using three additional reaction–diffusion partial differential equations. Transport of labeled low density liporotein (LDL) was fitted with experiments on rabbits. Matching with histological data for LDL localization was achieved. Also, 3-D model of the straight artery with initial mild constriction of 30% plaque for formation and development is presented.

In [18], authors describe the development of a minimally invasive wearable sensor platform to monitor a number of physiological correlates of mental stress. They propose a new spectral feature that estimates the balance of the autonomic nervous system by combining information from the power spectral density of respiration and heart rate variability. Validation is performed on a binary discrimination problem, where subjects are placed under two psychophysiological conditions: mental stress and relaxation. When used in a logistic regression model, the new feature set is able to discriminate between these two mental states with a success rate of 81% across subjects.

Finally, in [19], authors present an integrated e-health approach based on vascular ultrasound and pulse wave analysis for asymptomatic atherosclerosis detection and cardiovascular risk stratification. The approach is based on six main pillars: 1) integration of experts in different disciplines and creation of multidisciplinary teams; 2) incidence in public and professional education programs to give training in the use of new technologies and to shift the focus from asymptomatic cardiovascular disease (ACVD) treatment to disease prevention; 3) implementation of free vascular studies in the community (distributed rather than centralized healthcare); 4) innovation and application of e-health and noninvasive technology and approaches; 5) design and development of a biomedical approach to determine the target population and patient workflow; and 6) improvement in individual risk estimation and differentiation between aging and ACVD-related arterial changes using population-based epidemiological and statistical patient-specific models. The paper describes the main features of the project implementation, the scientific and technological steps and innovations done for individual risk stratification and subclinical ACVD diagnosis.

III. Conclusion

The research and development of emerging technologies for patient-specific healthcare is quickly growing. Research groups across the world are working to improve the design and development of such technologies, with the intent to integrate these improvements in the everyday clinical setting. The evaluation and the clinical validation of those emerging technologies, as well as their acceptance from the patients and the clinical staff require special attention and must be addressed.

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